

UNIVERSITY OF BRISTOL.



THE ANNUAL REPORT

OF THE

Agricultural and Horticultural Research
Station

(THE NATIONAL FRUIT & CIDER INSTITUTE),

LONG ASHTON, BRISTOL,

1919.

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INTRODUCTION.

The year 1919 has seen a welcome return to more normal conditions in the work of the Institute. The end of hostilities occurred too late in 1918 to permit of the resumption of the ordinary work on regular lines at the start of the new year, but during the course of its first few months most of the old members of the research and labour staffs returned to their duties, and the Station has subsequently been able to proceed more or less on its pre-war lines. Its position indeed is stronger in many respects to-day than in 1914, and there are prospects of further developments in the near future which should considerably increase its usefulness. These are referred to below.

It must not be forgotten, however, that its work has suffered severely during the past five years. In many directions, particularly where the experimental work in the fruit plantations is concerned, it has received a serious check, and in some cases a loss of time extending to several years will have resulted. There are instances where certain investigations will have to be restarted from the beginning, lack of necessary supervision and labour having rendered it impossible to keep them going satisfactorily during the war. Such setbacks have been counterbalanced, at least in part, by experience gained in new lines of work brought into prominence by the war, some of which appear worth further development, and also by the closer touch between the Station and those engaged in the practical side of the industries with which its work is concerned, which is in part due to a greater appreciation of the value of scientific research resulting from the services rendered by science during the war. Despite the loss of time it may well prove that the usefulness of the Institute has been increased to a degree which it might have taken many years to reach under ordinary conditions.

A number of staff changes during the year have to be recorded. Captain Gimingham was able to resume his position as chemist to the Station early in the year, but has recently accepted another appointment and will be leaving Long Ashton shortly. An arrangement has been made under which his services will still be available in an advisory capacity and the regrettable loss sustained by the Station in his departure will be in some measure tempered by the fact that his connection with its work will not be entirely severed.

The return of Dr. A. E. Lechmere at the end of 1918, after four years internment in Germany, was referred to in the last Annual Report. His untimely death early in the February following occurred while that Report was in the press and so could only receive brief notice in a footnote. He had just started his work at Long Ashton when an attack of pneumonia developed and he died after a few days illness. A detailed record of his career and a tribute to his memory were published at the time in the scientific press; but the present occasion cannot be allowed to pass without a brief expression of the feeling of admiration and pride felt by all connected with the Station for the invaluable services rendered by him in the internment camp at Ruhleben. None but those who have been privileged to hear the story of the camp life from his companions there can form any idea of the noble work accomplished by him, his wonderful influence, and the depth of personal affection inspired in all with whom he came into contact. His life there serves to provide some measure of the extent to which the Station is the poorer by the death of one distinguished as much for his personal character as for his high scientific attainments and brilliant promise.

During Dr. Lechmere's internment Mr. G. T. Spinks held a temporary appointment at the Station in his place. He has now been given a position on the permanent staff and is taking under his charge a section of the experimental work in progress in the fruit plantations.

As Mycologist in succession to Dr. Lechmere the services of Mr. S. P. Wiltshire, B.Sc., B.A., have been secured. Mr. Wiltshire is not new to the work at Long Ashton, having been connected with it while still a student at Bristol University. As in the case of Mr. Spinks, after taking his degree he was awarded a Research Scholarship by the Board of Agriculture and Fisheries. After courses of study at Cambridge and London, with intervals spent at Long Ashton continuing his investigations on Apple Scab and Canker, he was engaged during the war on bacteriological and chemical work for the Ministry of Munitions.

Captain T. Wallace, M.Sc., M.C., who was associated with Captain Gimingham during the latter part of the war in research for the Anti-gas Department of the Ministry of Munitions, was appointed Assistant Chemist to the Station last May. On Captain Gimingham's resignation he was given the post of Adviser in Agricultural Chemistry, and has now taken over the latter's work. He is a graduate of Durham University, and went to France with the Expeditionary Force in 1914, remaining on active service there and in Gallipoli until a severe wound caused his transfer to the Anti-gas Department.

As regards the labour staff the beginning of the year saw the Station largely dependent upon the temporary assistance of soldier

labour and of German prisoners. These were, however, gradually displaced by old members of the staff returning on demobilisation, and by the time the services of the former were no longer available the nucleus of a regular staff had been secured. Lack of housing accommodation has militated against the employment of an adequate number of skilled men, and until that difficulty can be overcome it will not be easy to equip the Station satisfactorily in that respect. As its work extends it becomes increasingly important that reliable labour with experience in practical fruit culture should be secured, and unfortunately very little local labour of that type is available.

No further land has been acquired by the Station during the year with the exception of a small orchard about $2\frac{1}{2}$ acres in extent with cottage and garden adjoining. The orchard in question contains for the most part cider apple trees of considerable age and in a more or less advanced state of decay. The varieties generally are of indifferent quality. There are, however, a few young trees of superior varieties, such as Kingston Black. As far as possible the orchard will be renovated, but those of the older trees which are in too bad condition to be dealt with profitably will be removed. The orchard lies by the side of the older plantations of apples and pears at the Station and has been a constant source of trouble as a harbouring place of insect and fungoid pests. Now that it has passed under the control of the Station a systematic attempt to cope with the pests can be made. Except for a few acres which it is proposed to retain as permanent grass, the remainder of the land acquired during the last few years has either already been planted with fruit trees and small fruit or will be during the coming season.

With the increasing area of the plantations the problem of the provision of adequate supplies of organic manure has required attention. Pig keeping on a small scale has therefore been resorted to. Thanks very largely to the help and advice of Mr. W. Nixon, the Live Stock Officer for the Bristol Province, a very promising herd of Gloucester Old Spot Pigs has been established and has quickly made a name for itself by successes at various Shows, including a First Prize at the Royal Show at Cardiff in June last with the only animal shown.

Another new side line of work, which was started during the autumn, has been taken up temporarily at the desire of the Ministry of Agriculture to meet a need of the fruit nursery trade resulting from the war. There is at the present time a serious shortage of fruit tree stocks owing to the fact that very few have been propagated since 1914. The Continental supplies, upon which the English nursery trade very largely relied in pre-war days, have been reduced to a very low ebb, and prices have risen to an alarming degree. Young stocks of good quality are almost unobtainable.

The Institute is therefore making an effort to assist the nursery trade in making good the deficiency in two ways. Firstly, during the current cider-making season the pips of some of the most vigorous and healthy varieties of cider apples which have been used in the cider house at Long Ashton have been extracted from the fruit, and a portion of the supply available, has been distributed to English fruit nurserymen. It has not been possible to meet all demands, but the seed already supplied should furnish at least a quarter of a million stocks, the greater part of which ought to be fit for working in 1921. Secondly, arrangements have been made to raise in addition a supply of seedling stocks at Long Ashton and the East Malling Fruit Experiment Station from the remainder of the seed extracted at the Institute, and it is hoped that as a result a further half a million stocks will be available for the trade for the planting seasons of 1920-21-22.

The Annual Tasting Day, which has been a feature of the work of the Institute since its establishment and was held in unbroken succession each year from 1905 to 1917, had unfortunately to be abandoned in 1918 and 1919, partly because the experiments on cider making for the time being had to be very largely suspended, and partly on account of the difficulty of organising parties of visitors from a distance. In place of this function the fruit plantations were thrown open for public inspection on the occasions of the Annual General Meetings of the Members of the Institute, which were held at Long Ashton in the two years named owing to the Shows of the Bath and West Society being suspended temporarily. These meetings took place in September and a general hope was expressed by the Members and other visitors that a regular Visiting Day at that season of the year would be arranged in future independent of the Annual Tasting Day. It has therefore been decided that in 1920 the latter shall be held on the first Thursday in May as usual and that in September, on a date to be fixed later, the plantations shall be thrown open to public inspection. Although no attempt has been made to organise visits from parties from a distance during the past two or three years, the number of persons visiting the Station has shown a tendency to increase steadily and several parties of growers, allotment holders, and others interested in its work have come from the surrounding district to see the experiments in progress.

With the return of more normal conditions there has not been so much occasion during the past year for the Station to undertake work of a special and emergency character as during the war period. The chief operation of this kind was the manufacture of an apple extract from pressed cider pomace for the Ministry of Food. This was referred to in the last Annual Report. That work continued during the first quarter of 1919 until no further

supplies of pomace were available, and from that time the connection with the Ministry's operations has ceased.

The Station has also during the year again been associated with the Food Investigation Board of the Department of Scientific and Industrial Research, and the Fruit Preserving and Vegetable Drying Committee of the Ministry of Agriculture in researches connected with methods of preservation of fruit and vegetables and with fruit products. Mr. C. P. Dutt, B.A., of Cambridge University, is now engaged at Long Ashton on behalf of the former body with an investigation on certain chemical changes occurring in fruit during ripening which appear to have an important bearing on its behaviour during storage. Arrangements are being made with the Department for experimental work on the cold storage of fruit during the coming fruit season at the Station. A number of miscellaneous experiments have been conducted for the Fruit Preserving and Vegetable Drying Committee, the results being subsequently tested on a larger scale at the experimental factory in charge of that Committee at Broom Junction. These have included the use of sweet oranges and lemons for marmalade, a point which arose as a result of the failure of the English fruit crops in 1918 causing a shortage of the jam supply and necessitating a larger output of marmalade than could be secured from the obtainable quantity of bitter oranges alone. Other questions receiving attention were the sugar content of jams in relation to their keeping qualities, factors affecting setting quality in jam, and methods of preserving fruit pulp. The Station has also continued its experiments on the utilisation of cider fruit for jam and jelly.

The remaining line of work with which the Institute has been associated with an outside organisation has been in the matter of the improvement of the condition of farm orchards in the West of England. As reported in the last Annual Report, a Farm Orchards Committee was appointed at the Annual General Meeting of Members of the Institute in September, 1918, to consider this subject, and as a result the Horticulture Division of the Ministry of Agriculture has become actively associated with the work. The original Committee has been reorganised and is now thoroughly representative of all the interests concerned. A great deal of useful preliminary work has been accomplished, including a detailed survey of farm orchards in representative districts of most of the Counties in the area. Fuller particulars are given in a separate section of this Report, to which special attention is directed. The subject is one of fundamental importance in relation to the future of fruit growing and the cider industry in the West of England. Provided that the hearty co-operation of the County Councils, landlords and tenants is forthcoming, there is a prospect that at last something effective may be done to remedy a state of affairs which seriously threatens

the future of the cider industry, endangers the supply of home-grown apples, and attaches to apple growing in the western counties a stigma which will not readily be removed.

Important developments affecting the future of the Station are immediately pending. Since probably some, if not all, may be realised before this appears in print, reference ought to be made to them here.

The first concerns the Governing Body of the Institute. Notwithstanding the marked changes which have taken place at Long Ashton and the extension and development of the scope of work of the Station, no modification has been made in the constitution of the Governing Body to adapt it to suit the altered conditions beyond the arrangement under which the affairs of the Station are administered by the Agricultural Research Committee, which is composed of representatives of Bristol University and of the Governors of the Institute. It is recognised that steps ought to be taken to develop and maintain the closest possible touch between the Institute and those who are engaged in fruit culture and related industries on a commercial basis. To that end proposals have been laid before the Governors which, if approved, will result in the appointment of additional Governors to be nominated by representative fruit-growers' Associations and other kindred bodies. It is hoped that they will serve as a link between the growers themselves and the Staff of the Station, so that the latter may be kept constantly alive to the needs of the industries concerned and at the same time assured that the results of their work will reach those for whose benefit it is primarily intended. These proposals are being put forward at a time when large additions to the Station are on the point of being made. The increased sums of money now at the disposal of the Ministry of Agriculture for the promotion of research have enabled it to provide for additional workers at the Research Stations. In the case of Long Ashton the number of those engaged on research will be increased to at least ten as soon as suitably qualified men can be secured. The existing laboratory accommodation available may suffice for immediate requirements, but some extension will probably be necessary by the time all the new posts have been filled.

The most pressing need of the Station for many years has been that of sufficient land for the development of field investigations. In 1917 it was reported that an arrangement with the Ashton Court Estate had been arrived at by which an option to purchase Fenswood Farm, which adjoins the Station, was secured. The Development Commissioners recently intimated that they were prepared to recommend the Treasury to make a grant from the Development Fund amounting to one half of the capital required provided that the University was prepared to find the other half. The University

accepted the offer, and Treasury sanction for the grant has now been received. Steps to complete the purchase are being taken. The acquisition of the farm will provide an additional 200 odd acres of land for experiments in fruit culture, and will remove all further anxiety in that direction. It will now be possible for the first time to frame a comprehensive programme of field experiments without restriction for want of land.

In presenting the following account of the investigations conducted in connection with the Station during 1919, reference must be made to the loyal co-operation rendered by all members of the administrative and research staff during the difficult period of reconstruction, without which it would have been impossible to have undertaken any considerable programme of work during the year.

CIDER MAKING EXPERIMENTS FOR THE SEASON, 1918-19.

BY OTTO GROVE.

Because of the abnormal conditions prevailing during the 1918-19 season—the great scarcity of apples and the high price (£20 per ton)—nearly the whole of the 10 tons of cider apples and perry pears allocated by licence to the Institute by the Ministry of Food was used for making small cider and perry. The following method was used. When the apples had been ground and pressed in the usual way the pressed pomace was broken up and mixed in an open vessel with sufficient cold water to cover the pomace. The mixture was allowed to soak for 24-48 hours before repressing. The expressed juice thus obtained was mixed with the pure juice obtained from the first pressing and cane sugar subsequently added. The quantity of sugar used differed in individual cases: the actual amounts used are stated in the detailed particulars of the ciders given below. The sugar was introduced either as a syrup made by dissolving the sugar in boiling water, or by directly dissolving it in the cold juice of the second pressing. The first method has the advantage that the possibility of introducing harmful micro-organisms from the sugar is eliminated. Otherwise the result is the same. The fermentation of the diluted juice proceeded normally, but was a little slower than in the case of pure juice.

The details of the respective ciders were as follows. For the most part the apples were mixed as regards variety, since except in a few cases individual sorts could not be secured in sufficient quantity.

Mixed Variety Ciders.

Mixed Fruit. No. 1. Mixed apples from the Nailsea district. Apples in good condition; milled and pressed October 9th, 1918. 243 gallons of pure juice obtained of the following composition:—

Specific gravity	..	..	..	..	1.051.
Malic acid	..	..	..	..	.62%
Tannin	..	..	..	..	.23%
Rate of fermentation at 25° C.	..	..	..	..	6.2

To this juice was added the juice of the second pressing, 160 lbs. of sugar, and water sufficient to bring the bulk up to 463 gallons of diluted juice, which then had a specific gravity of 1.044 and contained .37% of malic acid and .15% of tannin. The rate of fer-

mentation at 25° C. was 4.1. The cider was filtered on November 12th, when the specific gravity had fallen to 1.021. When tasted after one year in bottle it was found to be a fairly good sparkling cider with some sweetness. The gravity had fallen to 1.012 and the alcohol content was 3.5% by weight.

Mixed Fruit. No. 2.—Mixed local apples of fairly good quality. Milled and pressed October 25th, 1918. 240 gallons of pure juice were obtained having the following composition :—

Specific gravity	..	..	..	..	1.051
Malic acid	..	..	..	..	.51%
Tannin	..	..	..	..	.25%
Rate of fermentation at 25° C.	..	..	..	..	8.5

Made up with juice of the second pressing and 150 lbs. of sugar to 465 gallons of diluted juice with a specific gravity of 1.045, .38% of malic acid and .12% of tannin. Rate of fermentation at 25° C. 7.5. The cider fermented rapidly and was filtered on November 10th, when the specific gravity had fallen to 1.029. When tasted after one year in bottle it had a fairly good flavour and aroma. The specific gravity had fallen to 1.020, and the alcohol content was 2.8% by weight.

Mixed Fruit. No. 3.—Mixed apples from Byford in very good condition. 272 gallons of pure juice were obtained having the following composition :—

Specific gravity	..	..	..	..	1.057
Malic acid	..	..	..	..	.41%
Tannin	..	..	..	..	.42%
Rate of fermentation at 25° C.	..	..	..	..	7.2

Made up with juice of the second pressing and 67 lbs. of sugar to 365 gallons of diluted juice, which had a specific gravity of 1.054 and contained .31% of malic acid and .29% of tannin. Rate of fermentation at 25° C. 6.8. The cider was filtered on November 28th, when the specific gravity had fallen to 1.018. After one year in bottle the cider was found in good condition, with a clean, dry, rather bitter flavour. The specific gravity had fallen to 1.011 and the alcohol content was 3.6% by weight.

Mixed Fruit. No. 4.—Mixed apples from Exeter district in good condition. Milled and pressed November 16th, 1918. The pure juice had a specific gravity of 1.050 with .46% of malic acid and .17% of tannin. Rate of fermentation at 25° C. 5. 300 gallons of this juice were mixed with 200 gallons of the juice of the second pressing, and 200 lbs. of sugar. The diluted juice had the following composition :—

Specific gravity	..	..	..	..	1.050
Malic acid	..	..	..	..	.33%
Tannin	..	..	..	..	.13%
Rate of fermentation at 25° C.	..	..	..	..	5

It fermented normally and was filtered on December 7th, when the gravity had fallen to 1.025. When tasted after one year in bottle the specific gravity was 1.023. It was a rather sweet cider without much character. The alcohol content was 3% by weight.

Single Variety Ciders and Perry.

(1) *Royal Jersey*.—Apples from the Martock district. Very good condition. Milled and pressed October 24th, 1918. 90 gallons of pure juice obtained having the following composition:—

Specific gravity	..	..	..	..	1.054
Malic acid	..	..	..	..	.25%
Tannin	..	..	..	..	.43%
Rate of fermentation at 25° C.	..	..	..	..	4.3

Made up with juice of the second pressing and 45 lbs. of sugar to 180 gallons of diluted juice with a specific gravity of 1.042, .15% of malic acid and .21% of tannin. Rate of fermentation at 25° C. 3.3. The cider was filtered November 30th, when the gravity had fallen to 1.025. After one year in bottle the cider was in good condition and had a specific gravity of 1.021 with a good flavour and aroma. The alcohol content was 2.3% by weight.

(2) *Sweet Alford*.—From the Taunton district. A very good sample which was milled and pressed October 29th, 1918. 165 gallons of pure juice obtained with a specific gravity of 1.054 and containing .22% of malic acid and .14% of tannin. Rate of fermentation at 25° C. 5.6. Made up with juice of the second pressing and 66 lbs. of sugar to 265 gallons of diluted juice of the following composition: Specific gravity, 1.048; Malic acid, .17%; tannin .11%. Rate of fermentation at 25° C. 4.5. The cider was filtered on December 7th, when the specific gravity had fallen to 1.029. When tried after one year in bottle the cider was in good condition. It had a very sweet taste but otherwise not much flavour. The specific gravity was 1.027, and the content of alcohol 2.3% by weight.

(3) *Oldfield*.—Pears from the Arlingham district. Fruit in excellent condition. Milled and pressed October 21st, 1918. 80 gallons of pure juice obtained with a specific gravity of 1.065 and containing .65% of malic acid and .12% of tannin. Rate of fermentation at 25° C. 3.1. Made up with 55 lbs. of sugar and juice of the second pressing to 160 gallons of diluted juice with a specific gravity of 1.050 containing .40% of acid and .06% of tannin. Rate of fermentation at 25° C. 2.5. The perry was filtered on the 7th December, when the specific gravity had fallen to 1.033. After one year in bottle the perry was in good condition, and had a fairly good sweet flavour. The specific gravity was 1.027, the alcohol percentage 2.5 by weight.

Although the above small ciders and perry could not be compared for quality with good average pure juice ciders and perries, it must be admitted that most of them were quite palatable and constituted fairly pleasant light beverages. Certainly many pure juice ciders of distinctly poorer quality are frequently made. While not possessing the marked fruit character and full body of a high grade pure juice cider, they retain sufficient of the apple aroma and flavour to entitle them to the name of cider and their wholesome quality cannot be questioned. In seasons of scarcity and high prices of fruit they supply a very fair means of maintaining the output of cider.

SOME EXPERIMENTS ON ROPINESS IN CIDER.

BY OTTO GROVE.

It has been mentioned in an earlier report that a bacillus capable of causing ropiness in cider has been isolated at Long Ashton from a sample of ropy cider. This micro-organism was described in the 1917 report. During the summer of 1917 the following samples of cider, which at that time had been kept in bottles for over six months, were inoculated with the isolated bacillus:—No. 17 (Sweet Alford), No. 21 (Slack-ma-Girdle), No. 23 (Truckle), No. 29 (Pocket Apple), No. 34 (Royal Wilding), No. 36 (Hangdown), No. 37 (White Jersey) and No. 38 (Horner). All these ciders belong to the sweet and bitter-sweet group with low acidities and slow rate of fermentation, these types being especially liable to contract the disease.

The analyses of the ciders were as follows:—

No.	Specific Gravity	Malic Acid per cent.	Tannin per cent.	Alcohol per cent.	Rate of Fermentation.
17	1.021	.23	.15	3.5	3.3
21	1.030	.29	.14	2.4	3.2
23	1.023	.25	.15	3.1	2.8
29	1.025	.24	.37	3.2	3.6
34	1.027	.21	.29	3.3	4.5
36	1.023	.17	.33	3.4	4.3
37	1.024	.20	.18	2.5	7.5
38	1.024	.17	.25	3.2	2.7

The ciders were kept in pint bottles closed with screw stoppers and each bottle was inoculated with two drops of a pure culture of the isolated bacillus and placed at room temperature in the laboratory together with a double set of control samples. At the same time control samples were kept in the cellar of the cider house. The samples were examined at intervals during the autumn and winter of 1917, but no trace of ropiness was discovered. It was not until the early summer of 1918, nearly one year after inoculation, that some of the samples were seen to develop ropiness to a slight degree; but at the end of the summer all the samples with the exception of No. 23 had developed the disorder. The same was the case with the controls in two instances.

The results were as follows :—

No. 17.	Ropy, with small, stringy deposit	..	Controls : same.
No. 21.	Slightly ropy		.. " sound.
No. 23.	Sound		.. " sound.
No. 29.	Slightly ropy		.. " sound.
No. 34.	Ropy, with stringy deposit		.. " same.
No. 36.	Ropy, ditto, ditto		.. " sound.
No. 37.	Very ropy, with stringy deposit		.. " sound.
No. 38.	Slightly ropy		.. " sound.

The controls kept in the cellar were examined in July, 1919, over two years after bottling, and were all found to be sound with the exception of No. 34, which was ropy in all cases.

As will be seen from the above five out of eight samples inoculated turned ropy, whereas all the corresponding controls remained sound. The ropiness was consequently artificially produced by the inoculation with the micro-organism. In the case of No. 17 and No. 34 both the inoculated samples and the controls went ropy. No. 23 kept sound in both inoculated and control samples.

It is interesting to note how slowly the disorder develops. It is only when the ropiness is in a fairly advanced stage that a small deposit is formed. This, when the bottle is shaken, forms long strings in the liquid. It consists of a conglomeration of yeast cells, torulae and bacteria, of which the ropiness bacillus forms the largest proportion. As regards the changes produced in the cider, they are not very pronounced in the early stages apart from the oily consistency of the liquid. It is only in very bad cases that the cider gets cloudy. There is room for further investigation as to the conditions which favour the development of ropiness and determine the intensity of the attack : but it can already be regarded as demonstrated that sound ciders can be caused to become ropy by inoculation with the bacillus which has been isolated. It is hoped soon to start a close investigation of the chemical changes taking place in ropy cider during the different stages of the disorder.

THE RELATION BETWEEN THE RATE OF FERMENTATION AND THE CONTENT OF NITROGENOUS MATTER IN APPLE JUICE.

BY OTTO GROVE.

As is well known, the rate of fermentation of the juices of different varieties of apples varies very much. This fact has, of course, a very important bearing on cider making. Generally speaking, a slow rate of fermentation is wanted, since this makes it easy to retain some of the sugar unfermented,—in other words to make a sweet or medium-sweet cider. Fermentation is brought about by the action of the yeast cells growing in the liquid, and continues generally until all the sugar is consumed, provided the liquor is kept at a suitable temperature and that a sufficient amount of nitrogenous matter is present to enable the yeast cells to grow and multiply. At very low temperatures and in juices deficient in nitrogen yeast growth and, consequently, fermentation soon stop. Apple juices contain varying quantities of nitrogenous yeast food, and the rate of fermentation is within certain limits directly in proportion to the amount of nitrogenous matter present. If this amount is below the quantity which the yeast requires to produce a sufficiently large crop to carry through the fermentation completely, the fermentation will stop as the nitrogenous food becomes exhausted on account of the starvation of the yeast cells. Consequently it is desirable if a sweet cider is wanted that the content of nitrogenous matter should be very small.

To study the relation between the rate of fermentation and the amount of nitrogenous matter present in some of the well known varieties of apples, the following types were selected :—

- (1) Red Foxwhelp.
- (2) Lambrook Pippin.
- (3) Sweet Alford.
- (4) Royal Wilding.
- (5) Bedan des Partes.
- (6) Chisel Jersey.

Similar quantities, 125 grams, of the juices were weighed into Erlenmeyer flasks, which, after being sterilised, were provided with a fermentation lock closed with sulphuric acid. The flasks were

inoculated with a trace of pure yeast, and the rate of fermentation was determined by weighing the flasks at intervals. The losses in weight represented the amount of carbonic acid gas given off during fermentation. The flasks were kept at a temperature of 15° C.

TABLE SHOWING LOSS IN WEIGHT DURING FERMENTATION.

Flask No.	Weights in grams of culture on dates stated.					Total loss in weight.
	20/2/19	27/2/19	17/3/19	14/3/19	6/5/19	
1	210.845	209.80	207.50	206.10	202.13	8.715 Grms.
2	186.870	186.31	186.28	186.25	186.07	.80 "
3	219.095	218.04	216.47	215.41	212.78	6.315 "
4	182.055	181.11	179.58	178.43	174.80	7.255 "
5	184.020	183.09	181.28	179.93	176.50	7.520 "
6	209.363	208.41	207.82	207.30	204.76	4.603 "

The experiment was then stopped, as further weighings showed only insignificant losses in weight, and a microscopical examination of the yeast deposit showed that growth had ceased. The content of nitrogen in the juices and the percentages of sugar left were as follows :—

Flask No.	Nitrogen per cent.	Specific Gravity.	Sugar per cent.
1	.0221	.998	Trace
2	.0033	1.036	6.3
3	.0135	1.008	Trace
4	.0146	.999	"
5	.0168	.999	"
6	.0094	1.008	1.04

Nos. 1, 3, 4 and 5 fermented regularly until all the sugar had disappeared. No. 2 showed a very weak fermentation, which soon stopped, 6.3% of sugar being left unfermented. No. 6 fermented slowly, and over 1% of sugar was left when the fermentation stopped. If these results are compared with the amount of nitrogen present in the ciders it will be seen that No. 2 only contained .0033% nitrogen, and No. 6 about 3 times as much, namely .0094%. The four completely fermented juices contained from .0135 to .0221% of nitrogen. The minimum amount of nitrogen necessary to assure a complete fermentation is thus apparently slightly above .01%.

If to juices deficient in nitrogen, such as Nos. 2 and 4, is added some nitrogenous yeast food, such as sulphate of ammonia or yeast extract, the fermentation will proceed rapidly until all the sugar is fermented. The problem of altering a slow fermenting to a rapid fermenting juice is thus an easy one.

It is much more difficult to check the fermentation by depriving the juice of nitrogenous matter without otherwise interfering with

its chemical composition, and no satisfactory method is at present available. Consequently the reduction of the rate of fermentation, in rapidly fermenting ciders, a matter of necessity if sweet cider is to be produced naturally therefrom, must be affected by other means, such as filtration, until a practicable method of reducing the amount of organic nitrogen present in the juice is discovered.

The reason for deferring the determination of nitrogen present until the completion of fermentation was to enable it to be made in the presence of as little sugar as possible. The total quantity of nitrogen is so small that the presence of much sugar renders its determination with accuracy difficult. There is no ground for supposing that any loss of nitrogen from the fermenting vessel occurs during fermentation.

THE APPLE CANCKER FUNGUS.

By S. P. WILTSHIRE.

During the year, some progress has been made in the study of this disease, more especially as regards the culture of the organism in the laboratory and also concerning the spread of the disease under natural conditions.

The Culture of the Fungus.—The most interesting feature of this work was the production of the perithecial stage on artificial media. The strain of fungus used was isolated from ascospores of the fungus as follows :—

A Petri dish containing malt extract agar was inverted for ten minutes over a few moistened perithecia on a small portion of apple bark. The ascospores ejected from the perithecia were caught on the agar and could be identified under the microscope. The germination of one group of eight ascospores was observed and as soon as the resulting colony was about 2 mm. in diameter, a mycelial transfer was made to a sloped tube of medium. In this way a pure culture was obtained the origin of which was known.

The fungus was grown successfully on malt extract agar, malt extract gelatine, apple wood extract gelatine, Koch's gelatine, raisin salt gelatine, Claussen's media, cornflour extract agar, and glycerine potato agar. The growth of the mycelium varied greatly according to the medium used, some media producing a dense white cottony aerial growth, others a closely adpressed and almost invisible mycelium. Abundant conidia were produced in most of the cultures, but they were frequently of a much smaller size than the normal and did not resemble the typical long sickle-shaped conidia characteristic of the fungus. On Claussen's medium, however, although only a very poor growth of aerial mycelium was obtained, a fair number of typical conidia were formed. The culture which produced perithecia was grown on malt extract agar, the malt extract used for making up the agar (1.5% strength) being of 1.020 Sp. G. It was inoculated on 31/5/19 and on 14/8/19 red perithecia were seen to be forming on a somewhat raised circular area, about 1" from the bottom of the tube. No ascospores could be obtained from the unripe perithecia at this time, but on 19/9/19 drops of a milky fluid were observed at the ostioles, and this liquid was found to contain large numbers of

ascospores. The culture at the same time was producing in abundance conidia of the small type referred to above and the complete life cycle of the fungus may be said therefore to have been produced in pure culture. This fact is important in view of the discussion of the identity of the canker fungus which has been carried on in various foreign publications.

Other details concerning the life of the fungus in pure culture have also been obtained. The reaction of the secretory products was found to be alkaline and cultures made on media of varying acidity showed that the fungus could accommodate itself quite readily to such widely different acidities as 40° to $+50^{\circ}$ Fullers scale. On the more acid media, however, the growth resembled that of cultures incubated at too high a temperature and further the under side of the central portion of the colony was much more wrinkled on the alkaline than on the acid gelatine. With regard to the thermal relationships of the fungus, it was found that growth was completely inhibited at 33° C., whilst some slight growth took place at 30° C. There was some slight inhibition at 25° C., and the optimum temperature appears to be $20-22^{\circ}$ C. The fungus grew well at room temperature ($15-20^{\circ}$ C.), but very poorly in cultures left outdoors, where the temperature varied from $5^{\circ}-10^{\circ}$ C.

A new point of interest was also found in the sensitiveness of the various organs of the fungus to light. The germ tubes of the conidia when growing under well aerated conditions showed a decided negative heliotropism not so striking as in the case of *Botrytis cinerea*, but none the less quite definite. The mature mycelium does not appear to be sensitive to light at all, whilst the conidiophores, under healthy conditions are markedly positively heliotropic. This was especially evident in Petri dish cultures on Claussen's medium. The conidiophores on this medium, were localised into groups to some extent and were quite conspicuous. When examined under the microscope, the hyphae were seen growing towards the light, and if the direction of the rays of light acting on the fungus was changed by turning the Petri dish, the hyphae of the conidiophores showed a corresponding turning also. The biologic advantages of this sensitiveness to light in guiding the germ-tubes into the host and also in placing the conidiophores in suitable positions for the dissemination of spores, are obvious.

Infection through young buds.—It has been recorded by numerous observers that *Nectria ditissima* enters the host through young buds, but nevertheless it is commonly regarded merely as a wound parasite. Many attempts to infect through the uninjured cortex have been made by Aderhold and various other workers (see also Station Report 1913, p. 80) but without success. During the season of 1919, a severe attack of canker took place on certain crosses of Kingston Black and Medaille d'Or, raised at this Station for

breeding purposes, in which a large percentage of the buds became infected. This material enabled the process of infection to be investigated somewhat further. Numerous examples of young cankers evidently started from buds formed in the preceding autumn were obtained in August and observations made later (when the leaves had fallen) showed that the number of infections for 1919 to be considerably in excess of those for the previous years. Counts of the cankers on the wood formed in each year gave the following results :—

Year of growth.		No. of cankered buds found in 1919.		
1915	..	..	..	1
1916	..	..	..	4
1917	..	..	..	29
1918	..	..	..	434

The buds on the 1918 wood of course developed in the season 1919, the shoots formed during the latter year remaining entirely free from canker throughout the season. The trees in question had never been pruned and therefore the number of cankers formed on each year's wood gave an indication of the number of infections occurring during each succeeding year.

The counts were made on 20 different branches and the totals include all the cankers found on these branches. On one branch, almost every bud on the 1918 wood was cankered, the number reaching the very high total of 65. Besides the actual cankers, there were numerous cases in which the buds of 1918 had failed to develop in the Spring of 1919, and gave rise to the view that the fungus, in some cases, killed off the buds, or at least injured them so as to prevent their development, without succeeding in infecting the main stem. Such shoots, during August, showed long stretches of bare stem, and a tree severely attacked presented a partially defoliated appearance.

The exact means by which the infection of the buds is brought about is still under investigation, but it may be mentioned that mycelium and conidia of *Nectria ditissima* type were found between the bud scales of undeveloped buds taken from the trees in September. In this connection, it is interesting to note that another species of *Fusarium* is normally found only on the buds of the apple and pear where it succeeds in infecting the buds very completely. It is very doubtful if this parasite enters through wounds, as no signs of wounding are found on the infected buds, and it is possible that *Nectria ditissima* enters in the same way. The surfaces of the bud scales, especially the inner ones which are not exposed, are only covered with a very much thinner cuticle than is found elsewhere, and they obviously present a weak place in the plant armour. The buds of the potato tubers are similarly covered with only a very thin cuticle and thereby afford an entrance to that dangerous parasite of the wart disease,

Synchytrium endobioticum. On the other hand *Nectria ditissima* normally behaves as a wound parasite, and it has been suggested that the strains set up by the growth of the buds may result in small injuries by bursting open the cortex, thereby allowing *Nectria* to gain entrance. The matter is an important one and opens up the larger question as to some other diseases, which are now regarded as being only capable of infecting wounds, but which may yet be found to enter the healthy uninjured host.

This bud infection of canker is of importance economically, as it affords a possibility of some measure of control of the disease. Careful observations of many varieties on this Station have shown that this type of infection is responsible for quite a considerable amount of canker present. Some specimens of pear shoots sent in for investigation from Somerset, were excellent samples of typical bud infection of canker. Pruning, of course, eliminates much of the young wood each year and trees which are pruned do not suffer so extensively as those which are not. Standards are especially liable to bud infection, and very numerous cases have been found in the cider plantations here, especially of the Kingston Black, Cap of Liberty, and Strawberry Norman varieties. A method of preventing bud infection, therefore, would considerably reduce the incidence of the disease and such a method may possibly be found in spraying.

Preliminary Control Trials. (in conjunction with Mr. Spinks).—A preliminary spraying experiment on a small scale has been started with the object of testing the protective action of spraying against the infection of buds by *Nectria*. Twenty branches were selected on the Kingston Black $\times$ Medaille d'Or trees already referred to, and the number of cankers on each noted. Ten of these branches were sprayed and ten left to act as controls, the spray fluid used being copper stearate. Information as to the exact time of inoculation of the buds being unavailable at present a first spray was given in the middle of December, and it is hoped that a count of the number of bud infections on the 1919 wood of the sprayed and unsprayed branches will afford some indication as to the effect of this treatment. Canker, unlike many diseases, such as scab or potato blight, lives on inside the host from year to year and the effect therefore on the trees is a cumulative one. Consequently any spraying experiments will have to be continued over a period sufficient to allow the full effect of the treatment to be gauged.

In addition to the attempt to limit the action of the fungus spores by spraying, some trials were also made to stop the distribution of the conidia from old cankers by coating the latter with various covering substances. The first substance tried was red paint. Fourteen cankers were painted on James Grieve on August 29th, in the plantation, and ten on the Kingston Black trees in the cider orchard. Further, ten cankered shoots were selected, and placed

under a bell jar in the laboratory on September 1st; the cankers on five were painted, the other five serving as controls. Although the paint delayed the appearance of pustules slightly, both the painted and control cankers were fructifying within a week. The cankers painted on the trees were much slower in getting through the protective covering, but in almost every case finally succeeded in doing so, the paint drying up after a while and cracking along the original cracks of the canker scars. Vaseline and canada balsam were next tried in the laboratory, but were complete failures, the vaseline gradually soaking into the wood. Coal tar was tried finally and served quite well to keep the fungus within the stem, but experiments have yet to be made with this substance in the plantation.

The Relation of Woolly Aphis to Canker.—In the 1914 Report, some account was given of work attempted during that year on the relation of woolly aphis to canker. After showing that infection could not take place through the slight wounds made by the probings of the insect, it was stated that infection probably occurs during the late stages of the growth of the galls, in which the wood is exposed. During the year 1919 eight 5 year old bushes of the Allington Pippin variety, set aside for canker experiments became heavily infested by woolly aphis. The trees were left unpruned and untreated, allowing the attack to develop very severely. No signs of canker were visible throughout the summer, although there were three trees of Warner's King in the vicinity, suffering badly from canker, and which naturally formed an excellent source of infection. On November 25th, however, careful examination of the trees showed the presence of a few cankers in a very active state of development on the shoots formed in 1919, and the cankered areas were always found surrounding a woolly aphis injury. It was evident that infection had taken place through the galls, especially in the older galls, found towards the base of the year's growth. Infection of the woolly aphis galls had taken place during the late autumn in this case, and not in the year succeeding their formation—as generally held. No case was observed in which an unburst gall had become infected, all the scars surrounding gall wounds which had split open. The scars surrounding the point of inoculation (which might conveniently be termed primary scars) were much larger than usual, the lengths of five such scars being 5.3; 3.0; 7.0; 3.4 and 5.4 cms. respectively, an average of 4.8 cms., whilst the length of primary scars of artificial infections on Cox's Orange Pippin—a variety producing a large primary scar—were 2.5; 1.6; 2.0 and 2.5 cms. respectively, an average of 2.1 cms. The fungus grew very vigorously in the gall tissue which became very soft and disorganised, and the virulence of the disease was shown by the development of comparatively numerous pustules of typical conidia, even in the late autumn. The occurrence of conidia at such a late

time as December was remarkable, especially in view of the fact that perithecia were first observed on Lord Hindlip nearly a month earlier. It may be remarked incidentally that the type of fructification formed by the fungus does not depend wholly on temperature, but also on the supply of food available. The production of perithecia in pure culture at normal summer temperature, as reported above, showed that the stimulus for the formation of this type of fruit body is not necessarily low temperature, and the finding of conidia on woolly aphid infections in December, showed that the summer form of fructification also is not always determined by high temperature. It seems quite probable that alterations in the nutrition of the fungus produced by seasonable changes of the host, may also play some part in determining the type of fructification of the fungus.

The course of development of a canker infection of a woolly aphid wound was investigated as far as the limited amount of material available permitted. Young infections of woolly aphid galls were carefully sought and in few such cases were found.

Since no infection of an unburst gall was ever found, and also since repeated inoculations of unburst galls gave no infection, attention was centred on the injury resulting to the gall on the bursting of the cortex. The parenchymatous gall tissue formed as a response to the probings of the woolly aphid, grew rapidly and finally burst open the cortex by a shallow longitudinal split. The continued growth of the gall tissues beneath, caused the split to open out more and more until its edges were thrust wide apart. The aphides (a certain proportion of which winter on the branches), however, desiring to find a winter shelter, continued their attacks uninterruptedly, choosing the central portion of the cracks on which to feed, such portions being naturally the least well protected and the most succulent. The reaction of the host in the production of fresh cells became weaker and weaker as the autumn advanced, and the cracks penetrated deeper and deeper as the result of the continued tension brought about by the growth of the gall. The host still continued to form a phellogen layer over the exposed gall tissue, but the splits gradually extended until they approached the normal wood formed before the aphid attacks began. Once the wood elements were exposed, no phellogen could be formed over them, and hence any infecting fungi has free access to the interior. Although inoculation experiments have not yet been made, one very young natural infection was found in which a fungus (probably *Nectria ditissima*) had just succeeded in infecting a few wood vessels exposed by the cracking open of the gall tissue. Once infection has occurred, growth of the fungus took place very rapidly—more rapidly than the host could cope with it in the cortex, when in many cases, no phellogen layer was found limiting the progress of the invading hyphae. From

the present stage of the investigation, therefore, it appears that infection takes place during the late autumn, through the wood elements exposed by the splitting of the aphid gall. The dead tissue, cut off by the phellogen covering the exposed surfaces of the gall, was frequently heavily infested with fungi of various sorts, and evidently formed an excellent pabulum upon which infecting spores *Nectria ditissima* could obtain nourishment.

The number of galls splitting open, so as to expose the wood to infection was not so large as might be imagined. A large proportion never split open at all, and of those which did so, many did not expose the wood elements. It was therefore not surprising that on the Allington Pippin trees mentioned above, not more than 2% of the aphid galls had become cankered by the end of January. Some Allington Pippin trees in another plantation, about 250 yards away, did not show a single case of infection although heavily attacked by woolly aphid. Even this small percentage infection was sufficient, however, to cause considerable damage to a tree—canker resulting in the death of the branch, whilst the woolly aphid attack merely results in galls.

A. DIEBACK OF RED CURRANTS.

BY S. P. WILTSHIRE.

During the past three or four years, considerable trouble has been caused at Long Ashton by the sudden wilting and subsequent death of branches of the red currant bushes. An enquiry from Worcestershire concerning the same disease, focussed attention on the subject, and some preliminary investigations have been made regarding it. In addition to the material sent in for report, other specimens were obtained by Mr. Spinks from Pershore and Wisbech, and an abundant supply was also available from this station.

The first symptom of the disease was the sudden wilting of the leaves and fruit of one or more of the main branches of the bushes. This wilting occurred at any time of the season, but was most noticeable in July, when the branches were laden with almost ripe fruit. The wilted branches slowly but surely shrivelled up, the process taking some days to complete, and the leaves and fruit remaining attached to the branch for a considerable time.

The material from Worcestershire was examined and found to be heavily infected with a fungus in the cortex, and in the wood. Small portions of the diseased wood were cut by a flamed scalpel from the centre of the stem and of the cortex, and transferred to plates of malt extract agar. Six plates were thus inoculated, each by four pieces of infected material, and in almost every case a pure culture of a white sterile mycelium was obtained within a short time. This type (which may be termed type A) was isolated and subsequently a fungus identical in appearance and in culture was also isolated as the dominant fungus from five other cases of dieback, some of the material coming from Pershore and some from Long Ashton. The diseased branches, from which the portions for inoculation were taken, were placed in moist chambers, and from the exposed surfaces, a sterile white, aeral mycelium grew out in great luxuriance, and hung down the sides of the stems.

Numerous other plates of malt extract agar were inoculated in the same way from the material obtained from Wisbech, and also from Long Ashton, and from three lots of material, a characteristic pinkish fungus (type B) was obtained, once in conjunction with

type A. Four other types of fungi were also isolated, but they never occurred with sufficient frequency to indicate that they were the causal agents of the disease. In some cases they were associated with Type A, or Type B, and in others were obviously of a saprophytic nature.

The result of the somewhat extensive series of plate cultures was therefore the isolation of two types of fungi as the most probable agents of the disease. Cultural experiments were then made to induce the fungi to produce fructifications which would enable them to be identified. For this purpose cultures of the type A were made on malt extract gelatine, malt extract agar, corn flour agar and potato glycerine agar. The fungus grew slowly on the latter, forming a much less dense growth than on the malt extract agar, but it finally produced little black pycnidia containing innumerable long, narrow curved pycnospores, identical with those of *Cytosporina Ribis*. The process took some time, the inoculations being made on June 26th, 1919, whilst the pycnidia could not be recognised until the October 2nd, 1919. The cultures were kept at room temperature throughout. It is reasonable to regard the culture of Type A as being a pure culture of *Cytosporina Ribis*, although the development of mycelium from the pycnospores, which is really necessary in order to exclude the possibility of the presence of another sterile mycelium, has not been observed. The mycelial transfer, however, was made from the edge of a colony, and the culture did not appear to be contaminated with any other organism.

The production of pycnidia is interesting, since no inoculation experiments have been reported with this fungus in pure culture. Brooks and Bartlett obtained a sterile mycelium from diseased wood of the gooseberry, which was presumably *Cytosporina Ribis*, but they were not successful in obtaining any fructifications in their cultures of it. They were thus unable to identify the sterile mycelium which they isolated. The medium on which the fungus produced pycnidia was made up as follows:—

To 1000 c.c. of distilled water, 20—30 grms. of pulped potato were added. The whole was then thoroughly shaken and allowed to stand three or four hours, after which it was heated to boiling for five minutes and filtered. Forty grms. of glycerine were added and the liquid so obtained used for making up 1.5% agar. Cultures of a similar type of fungus on malt extract gelatine grew very well for a time, but very quickly died off. For instance, cultures inoculated on 25th June, 11th July, 30th July, 11th August, and 13th August, were all found to be quite dead on 24th September, 1919, whilst cultures inoculated on agar on 25th June, still remained alive on 2nd October, 1919. Consequently the use of gelatine media for the culture of *Cytosporina Ribis* was discarded in favour of agar.

The second type of fungus isolated, viz., type B, grew most

vigorously on malt extract gelatine, and produced quantities of conidia of the *Fusarium* type. The fungus *Nectria cinnabarina* has been associated with dieback disease of species of *Ribes* since the work of Mayer, although it is still regarded by some authors in America as being parasitic on the red currant in that country. In December last, some of the dead branches of the red currant bushes at Long Ashton showed extensive development of the coral red pustules of *N. cinnabarina*. It appears probable that the type B fungus, which was isolated from the base of the diseased portion of freshly wilted branches, is none other than *N. cinnabarina*, although further work will be necessary to confirm this point.

Some preliminary experiments have been made with the object of testing the pathogenicity of both the fungi isolated. In the case of *Cytosporina Ribis*, the first experiment consisted of five inoculations made on 30th June, 1919, on the variety Raby Castle in the plantation. The method of inoculating was to insert small portions of the sterile mycelium into incisions made in the stem by means of a flamed scalpel. On 6th August, 1919, one inoculation was examined by sectioning, and the fungus had then definitely infected the wood with the plentiful formation of wound gum. The cortex, however, appeared to be healing over to some extent. A second inoculation was cut on 9th January, 1920, and showed the cortex and wood round the wound to be heavily infested with fungal hyphae, and the attack seemed to be progressing successfully. The outward appearance of the stem gave no indication of infection. The other inoculations have been left to develop further. At the same time that the field inoculations were made, four similar inoculations were made on shoots of red currants, which were placed under a bell jar in the laboratory. After four days, the first inoculation was examined, and the fungus was found growing in the wood, although the infection was very small. The second inoculation which was examined after six days, showed a similar result, and the third and fourth inoculations after fourteen days also showed only a slight infection. These experiments are only in the nature of preliminary trials, and it is intended to make further experiments during the coming year, with the object of establishing the parasitic nature of *Cytosporina Ribis*.

With regard to *Nectria cinnabarina* also, some experiments have been made. Shoots of the Raby Castle variety were inoculated at four places over wounds, and then placed in a bell jar. After six days, the first inoculation was examined, and many hyphae were observed in the wood. The second and third inoculations examined after ten days, gave a similar result, and the fourth inoculation, which was left till fifteen days, showed that considerable browning of the wood had taken place, and hyphae could be recognised for a distance of 5 mm. above the edge of the wound. In view of the success of

this experiment, a further fifteen inoculations were made on July 2nd, 1919, on bushes in the plantation, with a corresponding number of non-inoculated wounds as controls. The first of these inoculations was examined on September 12th, 1919, and showed hyphae in the dead wood surrounding the edge of the wound. The second examined on 9th January, 1920, also showed the wood to be heavily infected by fungal hyphae.

It is proposed to continue this work as opportunity offers, for notwithstanding the difficulties of controlling diseases of this nature, greater acquaintance with their life history may possibly aid in devising means to counteract these costly parasites.

THE PRODUCTION OF CONIDIA IN PURE CULTURES BY THE BROWN ROT FUNGUS OF THE APPLE.

BY S. P. WILTSHIRE.

In the investigation of the fungicidal action of sulphur compounds, dealt with in another section of this Report, the spores of the brown rot fungus, *Sclerotinia fructigena*, were used extensively for germination tests on account of their sensitiveness to sulphur, their large size, their ready germination in water, and the plentiful supply of material available throughout the summer. The method of obtaining suitable spores for experimental purposes was to inoculate apples, chiefly of the Royal Jubilee variety, from a stock pure culture of the fungus, pustules bearing conidia being formed in three or four days. Inoculations made on 25th October, 29th, 31st, and November 1st, and on Royal Jubilee on November 2nd, however, completely failed to produce any conidia whatever, and merely resulted in the typical black rot form of the disease. In order to continue the original investigation a method of obtaining a satisfactory supply of spores had to be found and the results of the work undertaken for this purpose are thought to be of sufficient interest to be recorded here.

The ordinary stock cultures of *S. fructigena* on sterilised potato chunks and malt extract agar gave a huge development of mycelium with the final formation of dark sclerotia, but only a few spores in quite inadequate numbers. In view of the work of Mr. Spinks on this fungus, described in the Annual Reports for 1915 and 1916, in which he found that the type of rot produced was correlated with the variety of apple, the following varieties (found by him to give typical brown rot, which is accompanied by conidial formation), were inoculated early in November, viz., Reinette Obry, Crémière, Court Pendu Plat, Allington Pippin, King's Acre Pippin and American Mother. Inoculations were made from the same strain of fungus which had produced abundant conidia earlier in the year. Some of the inoculated apples were placed in moist chambers in the incubator at 25°C. and some were kept at room temperature. The result was extremely disappointing.

The variety Reinette Obry was the most successful. In its case by incubating at 25°C, first with a saturated and then with an incompletely saturated atmosphere, a certain quantity of spore pustules were produced. There was, however, a great tendency for bunches of sterile hyphae to replace the conidiophores. Of the other varieties, American Mother, King's Acre Pippin, and Court Pendu Plat after three or four weeks, produced many pustules, a number of which were fertile, and there was also a slight blackening of the skin of the apple. Cremière did not give quite the typical black rot, but in most cases produced no pustules at all, although in a few instances a certain number developed, some of which were fertile. In all cases, however, the few conidia which were produced were quite insufficient for experimental purposes, and the time of their development was abnormally long. These inoculations were carried out rather later in the season than those reported in 1915 and 1916, and the fruit used had been gathered in some time previously. It seems quite probable therefore, that the tendency of *S. fructigena* to form black rot rather than brown rot as the season advances, continues to be intensified much later than the end of October, when Mr. Spinks made his experiments.

From the fact that the factor which causes black rot is only developed when the apple approaches maturity, it was evident that the factor might be one of those compounds which disappear as the fruit ripens. As regards the changes which take place in this complicated process, our knowledge is very inadequate, but it is well established that the malic acid content of the apple is greatest in the unripe fruit. The influence of malic acid on the fungus was therefore investigated.

A 25% extract of apple was used for making up a 1.5% agar, and various quantities of malic acid were added. It was found that the addition of 1% malic acid prevented the agar from solidifying. The quantity of agar was increased to 10% without any success. Notwithstanding this, the laboratory assistant who made up the media inoculated one tube on November 14th, and after fourteen days the colony had grown to a diameter of one inch, and had produced an excellent crop of typical conidia. On December 2nd, however, the edge of the colony began to produce sterile mycelium, and never again reverted to the production of spores. This success was very promising, however, and further experiments were made along the same lines. First, a 1% solution of malic acid was injected in a number of apples of the Cremière and Reinette Obry varieties by means of a hypodermic syringe, one half of each fruit being left untreated. Inoculations were made in some cases at the junction of the treated and untreated portions, but the growth in every instance was the same. In no case did the addition of 1% malic acid result in the production of conidia. It is therefore pro-

bable that malic acid is only one factor in the formation of spores, and that another exists in the production of a substance very antagonistic to the brown rot form of development. The transformation of the malic acid alone is not sufficient to account for the deterioration in the stimulus to form conidia.

A liquid medium for the culture of fungi is, however, not very convenient and a number of trials were made of soaking potato chunks in malic acid solutions of various strengths. The first trial batch was soaked in 1% solution for 96 hours. One tube incubated at room temperature gave an extremely healthy development of conidia in six to eight days, and five other tubes incubated at 25°C. gave much smaller numbers. Increased strengths of malic acid were then tried, viz., 5%, 7.5% and 10%; the varieties used being Scottish Farmer, and Sharpe's Express. The 10% malic acid appeared to inhibit the growth of the fungus slightly although plentiful spores were obtained. Soaking in 5% malic acid did not reduce the growth of the fungus, but although many conidia were produced, the cultures were not so good as on potato soaked in 7.5% malic acid.

Various cultures have also been made on each of the following media, with the addition of an equal volume of 2% malic acid. Of these the plum wood extract plus the 1% malic acid produced an extremely good development of conidia in three or four days over the whole colony. Cultures were then made on pith soaked in a solution of this medium, as much air as possible being withdrawn from the pith by exhaustion under an air pump. The use of such a medium eliminated the action of the excessive starch content of the potato, and it was hoped that the effect of the malic acid might be intensified. The growth was very poor indeed, however, and any further attempts to improve on the potato soaked in 7.5% malic acid were therefore discontinued.

SOIL STERILIZATION.

BY C. T. GIMINGHAM AND G. T. SPINKS.

In the case of a number of fungous diseases of plants the plants are attacked through being grown in infected soil, which contains spores or mycelium of the fungus. In this way the disease will appear year after year on an infected piece of ground, and clean land may also be infected by the transference of soil from an infected area. It is clearly very desirable that some means of killing the fungus in infected soil should be found, but up to the present no method effective on a large scale has been found. During the last year therefore trials have been made of various means of sterilizing soil infected by two particular fungi, one of which, the cause of Wart Disease of Potatoes, at all events, is of very great importance.

WART DISEASE OF POTATOES.—These trials were carried out in 6-inch pots filled with a mixture of equal parts of local clean soil and of soil from a field which was badly infected with Wart Disease. This dilution of the infected soil was made owing to the quantity available being too small to carry out all the desired trials in undiluted soil. The whole mass of the soil was thoroughly mixed first and then the pots were filled, so that the mixture in all the pots was identical. A pot was found to contain 3.3 lbs. of soil, or 2.8 lbs. of air-dry soil, as the soil when the pots were weighed contained 15% moisture. In calculating the amount of sterilizing substance to be used it was assumed that in the field the substance would affect the top $4\frac{1}{2}$ inches of soil, and also that a layer of soil $4\frac{1}{2}$ inches deep and an acre in extent would weigh, approximately, 1,350,000 lbs. (air-dry). A square yard of soil $4\frac{1}{2}$ inches deep would weigh 280lbs. An application of 1 gm. of a sterilizing substance to a pot of soil was, therefore, equivalent to an application of 100 gm. or 3.6 oz. to a square yard in the field.

The pots of soil were subjected to various treatments on May 21st, usually four pots being used for each trial. The following treatments were given :—

Control	..	..	No treatment.
Bleaching Powder	..	..	1 gm. per pot.
Creosote	..	..	.5 gm. "
Chloro-picrin	..	..	.3 gm. "
Formalin	..	..	1 c.c. "
Powdered Chalk	..	..	1.5 gm. "
Powdered Chalk	..	..	7.5 gm. "
"Cymène"	..	..	.25 gm. "
Soil steamed $1\frac{1}{2}$ hours in autoclave at 100° C.			
Soil spread on tray in open and exposed to air and hot sun for two days.			

The bleaching powder, chalk, and "Cymène" were applied by turning the soil out of the pots, thoroughly mixing the powder with the soil with the fingers, and then replacing the soil in the pots. The soil was found to be acid in reaction and the smaller dose of chalk was calculated to be the amount required for neutralisation, the actual "lime requirement" of the soil having been estimated. The larger dose of chalk was intended to make the soil distinctly alkaline. "Cymène" is a proprietary substance recommended by the makers as a soil sterilizer.

The creosote and chloro-picrin were applied in a similar manner, the creosote having first been mixed with about 10 c.c. of water to facilitate even distribution. The formalin was diluted with 100 c.c. of water, half the soil was removed from the pot and half the dilute formalin applied to the soil remaining: the top half of the soil was then replaced and the remainder of the formalin added. These methods of applying the various substances probably ensured that all parts of the soil were reached by the sterilizing substances, and at all events the mixture would be much more thorough than would be obtained by ordinary methods in the field. The steam sterilization was done by placing the pots filled with soil in an autoclave, bringing the temperature up to 100° C. and keeping it there for 1½ hours.

The pots were placed outside in a shady situation and the soil was kept moist by watering when necessary. On May 28th one slightly sprouted tuber of "Sharpe's Express" was planted in each pot.

The control pots and those treated with bleaching powder, creosote, chloro-picrin and formalin were duplicated. This second series of pots was kept moist and in a warm greenhouse for a week in order, if possible, to encourage resting spores of the fungus to germinate before any treatment was applied. The treatment was given and the tubers planted one week later than the corresponding dates for the first series of trials.

A further series of pots received the following treatment *after* the tubers were planted on May 28th, two or three pots being used in each trial:—

Copper sulphate	..	100 cc. .2% solution	..	..	applied twice weekly.
Sulphur dioxide	..	100 cc. $\frac{1}{10}$ saturated solution	..	..	" " "
Formalin	..	100 cc. .1% solution	..	..	" " "
Bleaching powder	..	100 cc. 1% solution	..	..	" " "

On July 4th all the pots were examined, and in the majority of cases the treatment appeared to have had no effect on the growth of the plants, the haulm usually being equal to that of the control plants. The plants in the steamed soil, however, were distinctly larger and stronger than any of the others. The repeated doses of bleaching powder solution had caused the shoots to be very small, with very small yellow leaves, while repeated doses of sulphur

dioxide had, apparently, killed one plant, two others having shoots, only half an inch high, with very small dark leaves. From this date the repeated applications of copper sulphate, sulphur dioxide, formalin and bleaching powder were discontinued. At this time no trace of warts or infection of the lower buds of the haulm could be found on any of the plants. Three plants were also removed from their pots, but on none of them could any trace of infection be found on the underground parts: these plants were afterwards replaced in their pots and continued to grow.

Examination of the haulm on July 28th showed that plants in 14 pots out of 68 were distinctly infected and forming warts at the surface of the soil. One of these plants had been lifted on July 4th, and was at that time, apparently, quite uninfected. On July 28th the haulm of the plants which had received repeated applications of bleaching powder was tall and spindly, with very small yellow leaves; but those plants which had received sulphur dioxide had recovered from the treatment and were growing normally, though they were much smaller than the controls owing to the prolonged check which they had received while the treatment was being given. On August 11th numbers of other plants were visibly infected, and on August 18th all the plants were removed from the pots and the young tubers and rhizomes were examined. It may be noted here that keeping some of the pots damp and warm before applying any treatment produced no effect, and the results of this series of trials are therefore not given separately but are included with the others. The amount of disease found in pots which had received the various treatments is as follows:—

Controls	..	..	..	7 pots.	Disease in	7.	
Soil exposed	..	..	..	2	"	2.	
Soil steamed	..	..	..	4	"	0.	
Bleaching powder	..	..	..	8 pots.	Disease in	7.	
Creosote	..	..	..	8	"	6.	{ Only slight in 2;
Chloro-picrin	..	..	..	8	"	8.	doubtful in other 2.
Formalin	..	..	..	8	"	7.	Only slight in 2.
Chalk (normal)	..	..	..	4	"	4.	Doubtful in 1.
Chalk (excess)	..	..	..	4	"	4.	
Cymène	..	..	..	3	"	3.	Only slight.
Sulphur dioxide	..	..	..	3	"	3.	
Copper sulphate	..	..	..	3	"	3.	Slight.
Formalin (dilute : repeated)	..	..	..	2	"	2.	
Bleaching powder solution (repeated)	..	..	..	2	"	1.	Doubtful in 1.

It is evident from the above results that the only treatment which completely killed the fungus in the soil was the steam sterilization. Sections were cut through the eyes of the young tubers which had grown in the steamed soil and were examined under the microscope, but no trace of infection by *Synchytrium* could be found. This is contrary to the result obtained at Ormskirk by Mr. Snell, who

found that steam-sterilized soil was still capable of infecting potatoes. It appears, however, that in his trials the soil was only steamed for half an hour, and it is possible that the resting spores of the fungus are not killed by exposure to a temperature of 100°C . for so short a time as this. It is intended during the coming season to test the efficiency of steaming soil for different lengths of time.

The only other treatments which appear to have reduced the disease to any appreciable extent are the application of copper sulphate and excess of chalk, and perhaps creosote. These substances will be given another trial in the coming season.

Judging from the examination of the plants in July infection seems to have taken place only at some time later than July 4th, and it is possible that sterilizing substances applied after that date would have more effect. If the resting spores of the fungus had not germinated before that time they would probably not be affected by the treatment given, but if the treatment were given at a later date, after the germination of the resting spores, it is possible that it would be effective. On the other hand, if, as seems probable, only a portion of the resting spores germinate in one year and others are capable of germinating after lying dormant for several years the possibility of completely destroying the fungus by the application of any sterilizing substance seems very doubtful, and the treatment might have to be repeated year after year in order to be effective.

In connection with these trials it was intended to test the possibility of killing the fungus on infected seed tubers by immersing the tubers in hot water and different fungicidal solutions.

The diseased tubers, however, could not be obtained when wanted, but a number of trials were made with sound tubers in order to find what treatment could be applied to the tubers without killing them or spoiling their germinating powers. Three varieties of potato were used in the tests: "British Queen," "Sharpe's Express" and "Scottish Farmer," but there was no noticeable difference in their resistance to the treatment given.

Briefly summarised the results were as follows:—

Copper sulphate.—Immersion for 10 minutes in solutions up to a strength of 10% had no effect on the tubers, which sprouted well, the buds being uninjured. Immersion for one hour in a 10% solution killed practically all the buds, but one hour's immersion in a 1% solution caused only very slight injury to the buds and the tubers sprouted well.

Formaldehyde.—An immersion of 10 minutes in a 5% solution caused slight injury to the buds, but the tubers sprouted well.

Hot Water.—Ten minutes' immersion in water at 60°C . killed all the buds, while at 50°C . the buds were definitely checked but subsequently sprouted very well.

From the above results some idea of the limits within which sterilizing methods may be applied to seed tubers without injuring them is obtained, though the possibility of killing the *Synchytrium* within these limits does not seem promising. Actual tests of this have yet to be made.

RHIZOCTONIA ON CARROTS.—In previous Reports accounts have been given of experiments on the treatment of plots of ground infected with *Rhizoctonia* which attacked asparagus and carrots. In 1919 these plots were again treated with various fungicides and a crop of carrots was grown. With a view to making more detailed trials a quantity of soil was obtained from the untreated infected plot at Badsey and put in pots at the Research Station. Fifty pots were treated with different quantities of bleaching powder applied at different times, and pots of untreated soil were used as controls, carrots being grown in all the pots.

Unfortunately only negative results have been obtained both from the field plots and from the pots, owing to the fact that no disease whatever has appeared this year even in the untreated soil. The field plots at Badsey were examined in November and not a trace of disease could be found, the crop being quite healthy and as good on the control plot as on the others. It is difficult to account for the non-appearance of the disease, especially as it was severe on the plots in 1917, and it may be that it has simply "run its course" and that the fungus has died out through old age, though this explanation seems unlikely. Unfortunately, it was not possible to make any experiments or observations on the disease in 1918. Possibly the fungus may have disappeared owing to the absence of a suitable host in 1918, when tomatoes were grown on the plots and were apparently quite healthy. This again seems rather unlikely, considering what a wide range of host plants this fungus will attack. Still another possibility is that weather conditions, such as heat and drought, adverse to the growth of the fungus occurred at a critical time and killed the fungus, or at all events prevented its active growth and the infection of the host plant. If it is simply a case of active growth being checked at the time when the host would normally be attacked it is possible that the fungus is still present in the soil in a dormant form, such as a sclerotial stage, and that the disease might appear again next year, given suitable weather conditions. However, at present there is no evidence to show that any of these hypotheses are correct; but, whatever the cause, it is interesting to note the fact that the *Rhizoctonia*, after being rampant in the soil for several years, has now apparently spontaneously disappeared. The only difference found between the different plots was in the case of those to which creosote had been applied, and on those the plants had evidently been damaged and the crop diminished to some extent by the treatment.

Since no disease appeared in any of the pot trials these gave no information concerning the value of the various doses of bleaching-powder as a fungicide, but some information as to the effect of the bleaching-powder on the carrots was obtained.

In most of the pots the bleaching-powder was applied a week before the seed was sown, and in different pots doses equivalent to 1, 2 and 8 ounces per square yard in the field were used. It was found that the 1 and 2 ounce doses had no appreciable effect on the growth of the crop, which was equal to that in the control pots. The 8 ounce dose usually had a bad effect on the carrots, the leaves being pale and small and the weight of the crop being diminished by 10—50 per cent.

In one series of trials the seed was sown in all the pots on May 9th, and a 2 ounce dose of bleaching-powder was dug into the surface of the soil in different pots at fortnightly intervals from May 9th to July 27th. It was found that the carrots were unaffected by this treatment when the bleaching-powder was applied in May and June, but that the applications in July reduced the crop.

It thus appears that bleaching-powder to the amount of 2 ounces per square yard, a quantity which has already been found effective in reducing the disease on the field plots, can be applied to the soil before or at the time of sowing or while the carrots are actually growing up to the end of June, without producing any harmful effect on the crop.

Thanks are again due to Mr. R. C. Gaut, the Agricultural Organiser for Worcester, who applied the dressings of fungicides to the plots at Badsey this year and gave much assistance in other directions.

SPRAYING TRIALS.

By G. T. SPINES.

During the last year trials were carried out with several copper sprays to test their value in the control of Apple and Pear Scab. Only those varieties of apples and pears which were known to be liable to attacks of scab were sprayed and the number of trees available was small. Only one application of each spray was given, usually after the flower-clusters had opened but before the blossom was open; but the spraying with copper sulphate was done just when the buds first started to move. Owing to the dry weather experienced during spring and early summer very little scab appeared even on the control trees, especially on the apples; and it seemed useless to give a second spraying.

The varieties of pears sprayed were Louise Bonne of Jersey and Williams' Bon Chrétien, and the sprays applied were 1% Copper Sulphate as a dormant spray, 1% Bordeaux Mixture, and Copper Stearate of an equivalent strength. The trees were fair-sized bushes and they received on the average rather more than one gallon of spray per tree. At the beginning of June the trees were examined and marks were given to them according to the amount of scab present, the scale of marks ranging from 0, where there was no scab, to 10, where it was very bad. The amount of scab found on the various pear trees included in the trial is shown below:—

SPRAY.	AMOUNT OF SCAB.	
	Louise Bonne.	Williams.
Copper sulphate	2, 1, 8, 1, 3, 2, 2	1, 3, 2, 1, 3, 2, 3
Bordeaux	1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1
Copper stearate	2, 1, 2, 1, 1, 1, 2	1, 1, 1, 0, 1, 2, 1
Control	6, 7, 6, 6, 7, 7	4, 3, 4, 3, 3, 3

The above figures show that the untreated trees were distinctly more scabby than any of the others, while the Copper sulphate had checked the disease to some extent. But both the Bordeaux Mixture and the Copper stearate reduced the amount of disease to very small proportions. No further observations of the amount of scab present were made later in the summer as this early spring spraying could not be expected to prevent secondary infection later in the year, and as the trees were close together probably those

which had been sprayed would be infected by spores from neighbouring controls. Neither the Bordeaux mixture nor the Copper stearate caused any scorching or other injury to the foliage.

The varieties of apples which were sprayed were Frogmore Prolific, Bismarck, King of the Pippins, Devonshire Quarrenden and Cap of Liberty. All except the last were treated with the same sprays as in the case of the pears and also with a proprietary Burgundy mixture, while the Cap of Liberty was sprayed only with the Burgundy mixture. On the apples the Copper stearate was used in combination with an insecticidal mixture, soft soap and paraffin emulsion. From various causes this mixture was rather badly made and the spray as applied was by no means in a perfect condition. However, any fungicidal action which it exercised can be put down to the copper stearate, and the other ingredients of the mixture can be ignored from the fungicidal point of view. When the trees were examined at the end of June no scab could be found on the Frogmore Prolific, Bismarck or Cap of Liberty, and the attack was only slight on the other two varieties. On the latter the scab noted on various trees was as follows :—

SPRAY.	AMOUNT OF SCAB.	
	King of Pippins.	Devon Quarrenden.
Copper sulphate	.. 1, 0, 1, 1, 3	3, 3, 2, 3
Bordeaux	.. 1, 2, 0, 0, 0	2, 3, 2, 3
Copper stearate	.. 1, 1, 0, 0, 0	1, 3, 3
Burgundy	.. 1, 1, 0, 1, 0	3, 4, 2, 2
Control	.. 3, 2, 3, 5, 2	4, 5, 3

It will be seen that on the King of the Pippins all the sprays had reduced the scab to about the same extent, though the effect was not very marked owing to the small amount of disease on the controls. On the Devonshire Quarrendens there was no decided reduction of disease on the sprayed trees, though here again the attack was slight on all the trees. There was no evident damage done to the foliage by any of these sprays except on the Cap of Liberty trees, which were sprayed with Burgundy mixture, and on these the leaves were always scorched to some extent, usually moderately, but often badly.

In July a number of trees were sprayed with the Burgundy mixture, not to test its fungicidal action, but to find its effect on the foliage. One tree of each of the following varieties was sprayed, the varieties being selected to include trees both susceptible and resistant to spray injury :—Beauty of Bath, Cox's Orange Pippin, Lady Sudeley, American Mother, Lord Hindlip, Allington Pippin, Wealthy, Lord Derby, Royal Jubilee, and Warner's King. The spray was applied at a strength of 1%. Ten days later the Cox's appeared moderately scorched and there was a fair amount of defoliation. A trace of scorching was found on Beauty of Bath and Royal Jubilee, but none of the other trees showed any signs of

injury. But three weeks after the spray was applied all the trees showed very definite injuries. In every case the fruit was spotted, especially badly on Allington, but only slightly on Lord Hindlip and Beauty of Bath. On every variety the leaves turned yellow, though only slightly on Lord Hindlip, while those of Cox's and Lord Hindlip also showed some scorching. There was serious defoliation on almost every variety, Warner's, Wealthy, and Lord Hindlip being least affected in this respect; but Cox's was almost entirely defoliated.

The conclusions to be drawn from these trials, though it must be remembered that they are deduced from the results of one spraying in one season only, are that Bordeaux mixture, Copper stearate, and possibly Burgundy mixture are equally effective in preventing attacks of scab on apples and pears, while a dormant spray of Copper sulphate is less effective though not without value. Burgundy mixture, however, cannot be recommended as it causes serious injury to fruit and foliage: this probably applies to any Burgundy mixture, though the particular one tested was a proprietary mixture which had been used with success as a potato spray.

WOOLLY APHIS OF APPLE.

By A. H. LEES.

An attempt was made during the 1919 season to control this pest in such a way as to involve the least possible number of operations. It is clear that the usual method of hand painting of affected spots is not only laborious but almost impracticable on the large scale.

There are four possible sources of infection which have to be dealt with :—

- (1) Infection from stem forms remaining alive throughout the winter.
- (2) Infection from other trees in the neighbourhood by wind borne adults.
- (3) Migration from the roots.
- (4) Eggs.

It is therefore necessary to take all the sources into account before any satisfactory system of control can be arrived at. To deal with (1) and (4) a killing spray must be used. To prevent (2) treatment must be applied on a large scale so as to cover as far as possible all stem forms within the distance through which wind borne adults can travel, and lastly, a special treatment must be invented to deal with the root form.

The combined insecticide spray of nicotine paraffin emulsion containing :—

Soft soap	..	..	..	..	15	20lbs.
Paraffin	..	..	..	..	2	gallons
Nicotine	..	..	..	..	$\frac{1}{2}$	lb.
Water	...	..	..	..	100	gallons

is capable of killing the stem form even when no very high pressure is used. By using this formula therefore at the beginning of May, when the trees are in the right condition for spraying for aphids, apple sucker, capsids and caterpillars, no extra operation is required, and therefore no extra expense is involved. To deal with the root form is a more difficult matter. Direct action is impossible until some inexpensive soil fumigant can be found. Meantime,

however, it is possible to prevent the migrants from the roots obtaining access to the stems by means of grease banding. Migration begins about the end of May and continues during the summer for some time. Further a back migration from stem to root takes place in the late autumn so that if these migrants can also be caught it is all to the good.

By combining spraying with grease banding good results were produced, and there was a very marked decrease in the amount of infection compared with untreated trees.

In practice a spraying was given with the above formula just when the majority of the flower trusses had separated but before the flowers had opened. This occurs in an average season at about the end of the first week in May. As soon as spraying was finished grease bands were applied so that they were in position some two weeks or so before migration usually begins. If both sucking and biting insects are still present in too great numbers after the first spraying, as sometimes happens if some have been missed or eggs hatch out late, a second spraying with the combined wash may be done when the flowers have set. If, however, only one kind of insect is then present, namely, either biting or sucking, a simpler fluid may be used for the second application. In the case of biting insects lead arsenate is the obvious remedy, and in the case of sucking insects some cheap contact wash like one per cent paraffin emulsion.

By adopting these measures therefore it should be possible to control by two spraying operations and one grease banding aphids, apple sucker, capsids, caterpillars and woolly aphids. These comprise most of the commonest insect pests of the apple.

THE CONTROL OF LOGAN BEETLE BY CULTIVATION.

BY A. H. LEES.

This beetle is perhaps the worst disease with which logan growers are confronted. It is the cause of much loss of crop, weight, and much depreciation in the value of the berries. It renders the berry unfit for canning and bottling, and is probably the most frequent cause of plantations being grubbed. Its life history is a very protected one. It is hardly ever in the open, most of its time being spent as the adult in the ground, or as a larva in the berry. Consequently there is but a short time during which it is in reach of sprays. It is also difficult to kill by sprays, and the position is further complicated by the fact that the adults emerge from the soil over a prolonged period, so that in attempting to control by spraying several operations are necessary.

In the Report for 1917, a description was given of a field experiment, in which a certain system of spraying was employed. The method though successful was rather expensive and cannot therefore be considered as thoroughly satisfactory. Subsequently, it was noticed that logans growing in soil well cultivated during the summer suffered far less than others, growing in uncultivated soil, and the inference was drawn that the disturbance caused by cultivation was sufficient to cause the difference. In order to test this point, twelve rows of logans were treated in various ways as regards cultivation. Each treatment comprised three rows, so that four variations were tried. Owing to lack of room for turning horse cultivation could not be employed, but the action of a horse "cultivator" was imitated by a light pricking with a fork, the instrument being made to penetrate about three inches. The first three rows were treated in this manner about August, a time when the larvae have just entered the soil. The third three rows were treated in Spring, about the end of April, when the beetles are about to appear. The second three rows were given both autumn and spring culture, and the fourth three rows were left untreated, except for hand pulling of the largest weeds.

Towards the end of July the plants were examined for the presence of the pest. The method employed was to count between 150 and 200 berries on the middle row of each of the three treated rows. The following results were obtained :—

CULTIVATION.				ACTUAL NUMBERS.		PERCENTAGES.	
				Infected.	Sound.	Infected.	Sound.
Autumn only	..	..	..	37	146	25·2	74·8
Spring only	..	..	..	22	152	12·7	87·3
Autumn and Spring	..	..	..	26	126	17·1	82·9
None	..	..	..	89	178	33·3	66·7

These figures show that there was a marked increase of infection where no cultivation was done, but that the difference between any of the treated rows was not sufficient to draw any definite conclusion.

It will be necessary to continue the experiment on the same lines for a further period before conclusive evidence can be obtained.

BIG BUD.*

BY A. H. LEES.

The general facts of the life history of the mite causing this disease have now been known for some years. For the greater part of its life history, roughly from June to March, it has its home in the interior of the buds. During the other three months, from April to June approximately, it is migrating from the last year's buds, and is seeking entrance into the buds of the current year. Such a life history makes control by spraying very difficult, and while some such methods have been introduced they have not been attended with sufficient success when applied commercially to enable one to say that a cure has been found. More promise indeed was shown in a different direction, namely, the introduction of resistant varieties. Not so very many years ago the variety, Boskoop Giant, was introduced as an immune variety. For some time, for some reason, it apparently remained free, and its fall was somewhat sudden in the end. It did not even prove resistant but showed itself one of the most susceptible varieties. Following Boskoop Giant the variety called "French" was introduced and claims were made of its resistance. Its history was somewhat similar to Boskoop, but it is not on the average so severely attacked. The latest addition to the list is "Seabrook's Black" and this variety has undoubtedly stood the test of time far more satisfactorily. Its resistance, however, is not sufficient. Some years ago bushes of this variety were planted at Long Ashton, and though on the whole they now compare favourably in respect of resistance, with other varieties, yet there are a fair number of bushes that have become badly attacked.

These facts at once suggested that there must be some probably ascertainable reason why they relapsed at Long Ashton when, as there was every reason to suppose, their resistance was satisfactory in the place from which they originated. It must be pointed out that the originators of the variety, Messrs. W. Seabrook & Son, have never claimed immunity, but only resistance to the disease. That is they admitted that big buds might occur, but their number never

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increased so as to interfere with profitable culture. By the kindness of the firm, who sent for comparison shoots from bushes on which a few big buds did occur, it became possible to get some insight into the meaning of the variety's resistance.

These shoots showed but few big buds and those almost always were terminal ones. Instead, however, quite a large number of abnormal buds were noticed, the abnormality taking the form of extremely small size, or even complete absence. A section of these small buds showed that the original growing point of the bud had been killed probably in an early stage. It is hardly necessary to add that no mites, not even the remains, could be found. The whole appearance, however, strongly suggested that mite had attacked the young growing point and had killed it, thereby cutting off its own food supply. This hypothesis was verified the following summer, when buds were actually found in such a condition with mite *in situ*. The acceptance of this explanation naturally led on to the further question of why this variety behaved so whereas others presumably did not. Now there was nothing to show that the violence of attack was greater than in other varieties, so that the only supposition left was that the bud of Seabrooks had its food supplies cut off at an earlier stage than a non-resistant variety like Boskoop. A comparison between the manner of growth of Boskoop and Seabrook, at Chelmsford and Long Ashton, gave supporting evidence that this explanation was the correct one. It would of course be out of place and tedious to quote all the data on this point, and indeed, the details have been published elsewhere.

Broadly speaking, therefore, the theory adopted was that Seabrook's was resistant, not because mite cannot attack the buds' growing point but because the resistance by the growing point to damage was slight. This resistance is probably a question of the relative food supplies at the time of attack and for a short period after.

If this theory is correct for Seabrook's under ordinary conditions, it should also be correct for other varieties under special conditions. That is, one ought to be able to find such "killed" buds to some extent even on other varieties. This proved to be the case though they are not so abundant as they are in the Seabrook variety.

Now as already mentioned the behaviour of Seabrook's at Chelmsford, and Long Ashton, is quite different. At the former place it remains practically free from big bud; at the latter, it becomes, in individual cases, badly attacked. The biggest difference between the two places is one of rainfall; Chelmsford has on the average a dry summer, Long Ashton on the average a moist one. It is therefore probable that the two conditions run parallel, and that the moist summer, by prolonging what one may call for the sake of a better name, the vegetative season of the bush, increases the food

supply to the growing points, thus allowing the mite to form a big bud instead of a "killed" bud.

The same argument will apply to an extra wet season at one and the same place. Such a season should greatly increase the amount of big bud found at the following winter. A naturally wet or heavy soil may have the same effect, though it should be borne in mind that heavy clay soils also cause slow growth and might act therefore in the opposite direction.

The last factor to be mentioned in this connection is nitrogenous manuring. At first sight, according to current opinion, it should stimulate growth, and make the bush more susceptible, but the action of nitrogenous manuring on fruit trees, is probably not a simple one. Thus, it undoubtedly increases root growth, and therefore enables the plant to pick up more water. On the other hand it also increases leaf surface, and therefore must increase the amount of moisture transpired through the leaves. It does not therefore follow that nitrogenous stimulation will necessarily increase the food supplies to the axillary buds forming for next year though it would probably do so for terminals. In addition, it is known that the best commercial growers constantly use nitrogenous manures, though in moderate amounts, and that with ordinary care the disease does not usually increase at a great rate. It is probable therefore, that moderate nitrogenous manuring does not unduly favour the disease, provided always that the soil is not too wet at the critical stage.

The supposed influence of soil moisture may be found to account for the behaviour of plantations, in which the disease for some years remains quiescent, only to increase suddenly with alarming speed. Experience may prove that such conditions are brought about by a wet summer.

So far only the spread of the disease from last year's buds to the current year's buds on the same bush has been considered, but the question remains does it spread slowly or quickly from bush to bush. There are two sources of information that cast light on this point. The first, from observation shows that it is an extremely common thing to find a badly attacked bush next door to one that is free or almost so, and that badly affected bushes are often dotted about a plantation. This would indicate that infection to start with is largely a chance affair. This conclusion is supported by the author's experience of cutting down bushes.

It may be remarked that other experimenters' results have been rather conflicting, but that as the issue is rarely a straight one, being possibly complicated by external conditions, which are not always ascertainable from descriptions, it is better for the present to leave them outside the discussion.

Some years ago the bushes of a badly infected lot were very

carefully cut down. The cutting down was very close to ground so as to ensure that only very small and dormant buds were left. The operation was performed in winter. The following summer the bushes made strong growth and appeared quite healthy. In the subsequent winter it was found that a partial reinfection had taken place, and that the worst bushes bordered the uncut badly diseased ones, the infection getting less as the distance from the source of infection increased. In this case therefore, it appeared that reinfection took place comparatively slowly from the diseased bushes, and that the amount was governed by the laws of chance. One point that should be brought out in this connection is that cut down bushes according to the theory developed above, should be very susceptible, and this may account sometimes for such cases developing disease rather badly the first year, provided that some source of infection is left.

One may therefore conclude that increase of disease on one and the same bush may be quick or slow according to external conditions, but that increase from bush to bush is governed by chance and is generally slow.

During the last few years experiments, with a view to finding some control measure have been in progress, without however, obtaining any but negative results.

The usual difficulty in any spraying method during the migrating season is that, firstly, one cannot destroy the source of infection in last year's big buds, and secondly, that this entails extremely frequent sprayings in the attempt to prevent any mites reaching the buds of the current year. Spraying during the migrating season therefore usually becomes too expensive even if the disease is controlled. Spraying during the dormant season has usually been considered quite ineffective, but some amount of success in penetrating and killing big buds by the use of strong soapy sprays was obtained. Unfortunately, the method failed to obtain complete success owing to the fact that some big buds remain too tightly rolled throughout the winter season to permit of any penetration. Consequently they remained as centres of infection for the following year. Even a few may be sufficient to reinfect when one considers that, as shown by Pickering, a single bud may send forth as many as 3,000 migrants.

One other direction had also been investigated, namely, the action of lime-sulphur. It has of course long been known that sulphur is a powerful acaricide, and there was therefore the possibility that a control might be obtained by its use. Indeed Collinge's method, of dusting with lime-sulphur depended on this fact.

With the idea of eliminating a large number of spring sprayings lime-sulphur was applied in April, at winter strength just before the leaves appeared. There was, however, no visible result from its use.

Now the hope of a good result depended on sulphur remaining on the bushes during the season that migration took place, and this probably did not happen in the case just mentioned. There is some appreciable interval of time between the beginning of April and the period when the stems will be protected by leaves from rain. Further, this is often a period of April showers, which accompanied as they are so frequently by strong winds, would do a great deal to remove the sulphur deposited on the stems by spraying.

This year therefore it was determined to push the method to its economic limit and to use a strong spray as late as possible. The time therefore for using a winter strength spray was postponed till the first leaves were about the size of a sixpence. This occurs generally some time in early May, but will vary with the season.

A plantation of currants was selected which contained twelve rows of bushes and five varieties. These were Ogden's Black, Boskoop Giant, Carter's Champion, Baldwyn and Victoria. Each variety ran to six bushes in the row making 72 of each variety and 360 altogether. A few gaps occurred, but these were averaged in the results set out below. There were therefore twelve rows which ran across the five varieties. The middle four rows were left unsprayed, and the two outside four rows were sprayed at the time indicated, one with lime-sulphur at one in twelve, and the other at one in sixteen. Further, as soon as the flowers were set, the middle two rows of each of these four outside ones were sprayed, with lime sulphur at one in thirty. Leaves were of course then present. The experiment thus consisted of bushes sprayed at two winter strengths only, bushes sprayed at two winter strengths, combined with a summer strength applied later and a control of untreated bushes. The first effect to be noticed was that in the droughty period that followed, all the bushes, including the control showed an inclination to yellowness of the foliage, compared with black currants growing well outside the experimental area. This, however, disappeared when rain came and there was no noticeable harmful effect on the subsequent crops.

The second effect, noticed during the summer, was that there was more "oak leaf" on the unsprayed bushes than on the sprayed. These deformed leaves are a sure sign of a strong mite attack.

As soon as the leaves were off at the end of the season each individual bush was examined and placed in one or other of four classes numbered from 0 to 3, according to the intensity of attack, class 0 being the least attacked. This is of course a question of personal judgment, as it is impossible to count all the buds present on so many bushes, and counting buds on so-called average twigs would involve exactly the same personal error, owing to the difficulty of selecting average twigs. To judge of results, it is necessary not to calculate what bushes in the experiment show the least attack,

but to take into account their previous infection, since, as already pointed out, the distribution is comparatively erratic. The bushes selected have been under observation for some years, but owing to pressure of teaching work in 1918, they were not marked. The 1917 figures are, however, available and may serve as a basis of comparison.

The method of computing results was the following :—

First of all, for each variety, the increase in intensity of attack, from 1917 to 1919, as measured by the alteration in class numbers, was calculated for the control. This figure which one may call the "expected increase" was added to the 1917 figures for the sprayed rows. This gave, therefore, the expected figure for the sprayed rows. The difference between the actual 1919 figure and the expected gave a minus figure indicating the amount of reduction in the disease due to the spray.

Though it was evident from a glance at the figures so obtained, that a considerable reduction had taken place owing to treatment it was not clear at first, owing to results being in different directions, in different varieties, whether there was any superiority in any of the strengths or frequencies employed. When, however, these "difference from expected" figures were added together the results became apparent. Thus each of the five varieties had two sets of bushes under "one spray" treatment and two sets under "two spray" treatment. Adding these for the ten cases involved gave, in the case of the winter treatments only, the figure 8.57, and for two treatments (winter and summer strength) 8.41. It was clear, therefore, that the second spraying in no way enhanced the effect. The average for all treated bushes over control gave a reduction of 8.45 (for 10 cases), or .845 per bush. This means that the spraying treatment (all taken together) shifted the "average" bush back nearly one whole class.

The figure for 10 cases of weaker strength spraying was 5.84 against 11.30 for the stronger, showing that the one in twelve formula was twice as effective as the one in sixteen and that the stronger treatment thus shifted back the "average" bush under such treatment well over one class (*i.e.*, 1.154).

A comparison between the actual figures obtained in 1919, and the expected figures is shown in the accompanying table.

	CONTROL.	WEAKER SPRAY.	STRONGER SPRAY.
Average actual figure for 1919	1.522	.528	.436
Maximum 3.			
Average expected figure for			
1919	1.522	1.112	1.566
Maximum 3.			

This shows that if only the actual figures had been taken, though the expected figures for the control, and stronger spray bushes were nearly the same, the figure for the weaker spray would have shown more relative benefit than actually occurred, owing to its lower expected figure. By means, therefore, of this method, inequalities in the original infection are smoothed out.

From these facts the following conclusions may be drawn :—
Under the conditions at Long Ashton, for the five varieties named, and for the season of 1919.

- (1) Lime-Sulphur, at the rate of 1 in 16, or 1 in 12 applied as soon as the first leaves were as big as a sixpence, resulted in a considerable decrease in the number of big buds the following winter.
- (2) That a strength of 1 in 12 was approximately twice as effective as a strength of 1 in 16.
- (3) That a second spraying at Summer strength (1 in 30) did not result in any increased efficiency.

The season of 1919, was exceptionally dry in the early summer, and this may well have favoured the treatment. The success of the method can only be assured by repeating it for some years. At the same time the encouraging results obtained are sufficient to justify an immediate publication in order that any growers interested in the disease may have the chance of trying it.

SULPHUR AS A FUNGICIDE.

By B. T. P. BARKER, C. T. GIMMINGHAM AND S. P. WILTSHIRE.

The following account of investigations on the fungicidal action of sulphur and certain of its compounds, which were begun early in 1919, is to be regarded as a preliminary report. It presents in a condensed form the results of many series of experiments which have covered a very wide field and have necessarily been concerned with many side issues as well as with the central problem. On account of the variety of subjects which have required attention the record of the work divides itself very largely into a number of separate compartments not always very closely connected; and it is therefore proposed in the first place to take a general survey of the results and to indicate the conclusions drawn therefrom, before proceeding to deal in more detail with the individual researches.

In practice sulphur has mainly been used as a fungicide either in an uncombined state in the form of flowers of sulphur or in combination with other elements as sulphide or polysulphide, *e.g.*, liver of sulphur, lime sulphur, and Salmon & Eyre's recently advocated ammonium polysulphide. Although its use in one or other of these forms dates back so far that it is probably the oldest of all fungicides, and although its mode of action has been much discussed and investigated, it is remarkable that its toxic properties are still but little understood; and no explanation of them which has yet been proposed has met with general acceptance. The methods of using sulphur for fungicidal purposes must therefore be regarded as being up to the present of a rule-of-thumb character, and there is no certainty that it is being used or applied in the most efficient way.

The work here dealt with was started partly with the object of clearing up those points, if possible, but mainly to investigate more closely the apparent action of sulphur at a distance. Salmon & Eyre have recorded cases of unsprayed gooseberry bushes which have been defoliated as the result of the spraying of adjacent plots of bushes with lime-sulphur. It is also a well-known fact that flowers of sulphur applied in paste form to hot water pipes in green-houses will hold in check diseases of the mildew type on plants growing in those houses, and may, unless care is taken, produce defoliation of certain kinds of plants. Such results suggest that

sulphur in "vapour" form or some gaseous compound of sulphur can exert toxic action on plant life at a distance from the point at which it is generated.

From the point of view of control of plant diseases an action of this kind is particularly interesting, since the present methods of control are admittedly far from perfect. Spraying in liquid or powder form is the most generally serviceable; but either method presents the same fatal drawback. The essence of spraying in general is prevention of infection, and this is usually accomplished by depositing upon the plant a protective covering of some substance, which by its toxic action on the parasite renders the latter powerless to infect, if it alights on the plant at any point covered by the spray. In practice no protective coating is complete and all new growth subsequent to spraying is absolutely unprotected. At the best, therefore, spraying, although the most efficient method of disease control yet introduced, cannot be regarded as anything more than a useful temporary expedient. A more effective type of control may be imagined around the plant if an atmosphere could be maintained charged with sufficient antiseptic qualities to prevent the growth of any parasite, without at the same time injuring the plant itself. For that reason the attention of plant pathologists to volatile fungicides seems clearly indicated, and it is surprising that in spite of obvious difficulties of practical application so little has hitherto been done in that direction.

That sulphur and its compounds of the polysulphide type might be worth consideration in that connection follows from the facts above recorded and from their behaviour after application in fruit plantations, when on warm dry sunny days a distinct "sulphur" smell can be readily detected.

The central problem of the investigations here recorded was to determine how sulphur acts as a fungicide. The case of the action of sprays of the sulphide and polysulphide type was also involved since it is known that they decompose rapidly with the separation of sulphur as such in finely divided form.

As a first step the nature of the changes taking place after the application of these spray fluids was examined, and it was found, as was to be expected, that the sulphides and polysulphides decompose rapidly after spraying, sulphuretted hydrogen being given off in gaseous form, and finely divided sulphur deposited at the same time. This action appears to be accelerated by the presence of carbon dioxide in the atmosphere. In addition to the sulphur the solid residue of the spray contains small quantities of the sulphate and thiosulphate salts of the particular base used and also the carbonate of the base. Thus lime-sulphur gives a deposit of sulphur mixed with calcium sulphate, thiosulphate and carbonate, and liver of sulphur the corresponding salts of potash. Ammonium polysulphide does not

give the same proportion of solid residue, since the ammonium compounds formed tend to volatilise.

In what manner, then, are such sprays toxic? A triple effect has been demonstrated. At the moment of application to the plant a direct toxic action proceeds which is due to the presence of the sulphides and polysulphides as such. The toxicity of these compounds in the strengths applied has been proved. Their immediate action on any fungi present is doubtless supplemented to some extent by the sulphuretted hydrogen which at once begins to be generated. It is a highly toxic substance. Its action, however, must be of brief duration, because its production soon ceases and it is very quickly dispersed in the surrounding atmosphere. These effects are transient on account of the rapid decomposition and removal of the substances concerned; but they suffice to permit of these sprays being grouped among those possessing direct killing properties. They do not, however, account for the lasting protective action which practice has shown these sprays to have. This must be due to one or more of the substances left in the solid residue after the initial decomposition of the spray. The sulphates and carbonates can at once be ruled out of account as not being sufficiently toxic under the conditions obtaining. The thiosulphates, while more toxic, are not present in the required amount. Moreover, they are easily soluble and tend to be removed in the moisture or rain dripping from the leaves. By the process of elimination it follows that the active agent must be the sulphur itself.

The problem thus becomes narrowed down to the method of action of sulphur. This subject has been much debated by previous investigators, and three distinct hypotheses have been advanced and received varying degrees of support. Mach and others believe it to be due to the gradual oxidation of the sulphur to sulphur dioxide, which is a highly toxic gas. Pollaci has suggested its transformation into sulphuretted hydrogen, and Mares & Mohr hold that it acts of itself, by its own vapour. A fourth suggestion, that of its conversion into sulphuric acid also needs consideration.

The account of the experiments made at Long Ashton, which follows, shows that under ordinary practical conditions none of these hypotheses meet the case. The quantity of any of the compounds mentioned, which may be formed as the result of atmospheric agencies, or in solution, is not sufficient to produce the observed toxic effect which is associated with sulphur treatment: nor are any of the impurities which occur in commercial sulphur preparations responsible.

Critical experiments carried out recently have demonstrated the method by which sulphur at a distance from the plants under treatment (as in the hot water pipe method in a greenhouse), is brought into contact with the fungus; and it is intended to

publish shortly the details of these experiments and the evidence on which the above statement is based.

The case of sulphur applied at a distance is thus brought into line with that of sulphur applied directly to the plant by dry or wet spraying, and the question as to how sulphur reaches the fungus is disposed of. What happens when it reaches it still remains to be considered. On this point a definite answer cannot be given until the investigation has been carried further, but the possibilities appear to be reduced to three alternatives. Sulphur is not sufficiently soluble in water to be able to enter the cell to a toxic extent in ordinary aqueous solution: but it is conceivable that the fluid which bathes the cell wall, and maintains it in a moist condition and which presumably corresponds more or less closely in its composition to the sap of the cell, may possess greater solvent properties than water, and may therefore be the means of conveying to the protoplasm of the cell a toxic dose of sulphur. Or, alternatively, this fluid, which probably contains organic matter, may actually act chemically on the sulphur, with the resultant formation of a toxic sulphur compound, possibly of a sulphide or polysulphide character. The solvent or chemical action of a dilute agar solution on sulphur, referred to below, may be considered as furnishing support to one or other of these suggestions. The third alternative rules out a direct chemical action, and is based on the idea that matter in the form of finely divided and actively disseminated particles possesses peculiar properties of an irritant character which stimulate to an injurious extent cells exposed to their action. There is certain evidence pointing in this direction, consideration of which must for the present be reserved.

This in outline represents the course of the investigations, and the conclusions arrived at. The remaining portion of this article deals with the actual experimental work involved.

The Sulphide and Polysulphide Constituents of the Lime Sulphur and Analogous Spray Fluids.—The exact composition of the lime sulphur spray fluid is not known with any certainty, but the various sulphide and polysulphide compounds present are almost certainly the substances to which any direct fungicidal action is due. At the commencement of this investigation therefore, various experiments were made with the object of determining the fungicidal values of the sulphide and polysulphide constituents of the spray fluid. It is characteristic of these substances that they undergo rapid decomposition on exposure to air and therefore, in testing them, certain precautions had to be taken in order to be sure that the substance under treatment was not mixed with any of its decomposition products. In the first place, the sulphide and polysulphide solutions were prepared in as pure a state as possible, and secondly the tests of their toxicity were carried out immediately they had been prepared.

On account of the instability of these various compounds, it was impossible to obtain information regarding their relative fungicidal action by means of hanging drop cultures, using solutions of the compounds as the culture medium. The only means of determining the toxicity was to allow the freshly prepared solutions to act on the spores of fungi for short periods, during which the solutions would not decompose to any appreciable extent. The following method of comparing the toxicity of the sulphide and polysulphide solutions was therefore adopted. A small quantity of the freshly prepared solution of the sulphur compound was inoculated with spores from a pure culture of a fungus, by means of a platinum needle, the spores being stirred well into the solution in order to wet them as much as possible. At intervals of 10 minutes, 1 hour, and 24 hours from the time of inoculation, a loopful of the solution was withdrawn, and added to a tube of melted malt extract gelatine at a temperature of not more than 30° C. The gelatine tube was then thoroughly shaken and placed in a slant position under the tap until the gelatine had set. The tube cultures thus obtained were incubated at room temperature, and growth was observed at regular intervals according to the rate of growth of the fungus.

The concentration of spores in the solution varied within limits, but every endeavour was made to keep it as constant as possible. The fungi used were *Nectria ditissima* and *Rhizopus niger*, and the spores were taken from vigorous cultures on malt extract agar. The toxicity of the solutions of the sulphur compounds was estimated from the growth on the slope cultures, no germination resulting from the death of all the spores, a heavy growth indicating that the spores had not been affected by the treatment they had received, whilst intermediate stages could frequently be distinguished where only partial killing had taken place. The time taken for the development of a culture often showed the extent of the toxic action of a solution, a large number of spores producing a much more rapid growth than a small number. The amount of decomposition which took place during the exposure of the spores to the action of the solutions was much greater in the case of the higher polysulphides than in the other solutions as shown by the perceptible change in the appearance of the liquid. It was found subsequently, however, that the toxicity of these polysulphide solutions decreases rather than increases with their decomposition, and this fact therefore discounts largely any fungicidal effect which the decomposition products might exert.

The first solutions of which a comparison of toxicity was made were those of sodium hydrosulphide and sodium sulphide. The strength of the solutions of these substances used for the test was 4%, a much higher concentration than occurs in the normal spray fluid. It served, however, to bring out very clearly the high toxicity

of the sodium sulphide solution as compared with that of the sodium hydrosulphide. The former killed off all the conidia of *Nectria ditissima* and *R. niger* within 10 minutes, whilst the latter solution required 1 hour to kill off the *Nectria* spores and was not successful even after 24 hours in killing off the *Rhizopus* spores.

The next experiment consisted in testing the toxicity of solutions of sodium sulphide, and of sodium polysulphide solutions containing various proportions of sulphur, and the strength of the solutions in this experiment was reduced from 4% to about .4% so as to approximate more closely to the strength of the spray fluid. There was a marked difference in the behaviour of the two fungi used for experiment as well as a difference in the action of the compounds themselves. All the solutions were successful in killing off the spores of *N. ditissima* within 24 hours. In the case of the shorter periods of exposure, however, a difference was noticeable. Two conidia resisted an hour's exposure to sodium sulphide, and four to a polysulphide solution saturated with sulphur (Soln. C.), whilst all the spores were killed off by a polysulphide solution containing sulphur corresponding to the formulate No. 2, S₂ (Soln. B) within the same time. Many spores germinated after immersion in the sulphide solution for 10 minutes, none after immersion in the Soln. B, and a small number after immersion in the saturated polysulphide solution. Five repeat experiments were made, using solutions of approximately .5% strength, with however similar results, except that on an average 9 spores were found capable of germination after 10 minutes immersion in Soln. B, and also that two cultures were obtained in which two and three colonies respectively developed from spores immersed for one hour. *Rhizopus niger* was distinctly less sensitive to the solutions than *N. ditissima* and in no case even after 24 hours immersion were all the spores killed. From these experiments therefore it appeared that there was a progressive increase in toxicity from the hydrosulphide, the sulphide to the lower polysulphide, whilst curiously enough the higher polysulphides did not appear to be quite as toxic as the lower ones, a result which has not been investigated further as the course of the work did not lead in that direction, and which may be due to the extremely rapid decomposition of this solution causing a lowering of its fungicidal value. With the exception of this irregularity, however, these results agree well with those of Eyre, Salmon and Wormald on the fungicidal action of the ammonium sulphide and polysulphide compounds.

Loss of Toxicity of the Polysulphide Solution on the Deposition of Sulphur.—In the case of the higher polysulphide solution, a distinct deposition of sulphur took place within the 24 hours, during which the spores were exposed to the solution in the above experiments. An experiment was therefore made to determine the effect of the

deposition of the sulphur on the toxicity of the polysulphide solution. For this purpose, five sterile test tubes were filled with 2c.c. of a freshly prepared solution and the cotton wool plugs replaced. Tube I was inoculated immediately, Tube II after 24 hours, Tube III after 48 hours, Tube IV after 5 days, and Tube V after 6 days. Subcultures into malt extract gelatine at 30°C. were made from each tube, 10 minutes and 1 hour after inoculation and also in the case of Tube V, 24 hours after inoculation. No growth occurred in cultures from Tubes I, II and III after 3 days incubation, whilst Tube IV and V showed enormous number of spores germinated in a similar period. After 5 days incubation, cultures made from Tube I, showed a number of germinating spores, those from Tube II showed many colonies developing, and those from Tube III showed an excellent growth of mycelium. The conclusion drawn from this experiment therefore was that the toxicity of the polysulphide solution gradually decreased with the deposition of sulphur from the solution.

Toxicity of Caustic Soda and Neutralised Polysulphide Solutions.—A comparison of the toxic value of a .3% sodium sulphide solution and a .1% caustic soda solution showed that they had a very similar fungicidal value. It was possible therefore that the toxic action of the sulphide solution might be due in part to the alkalinity of the solution. The toxicity of a .5 % sodium sulphide solution was tested therefore, against a portion of the same solution made neutral to phenolphthalein and another portion made neutral to methyl orange. There was no difference in the case of *R. niger*, and only a slight reduction in toxicity after exposure for 1 hour and 24 hours in the case of *N. ditissima*. A comparison of the action of a .5 % solution, of the lower polysulphides of sodium with a similar solution neutralised, however, showed that the latter was apparently as toxic as the untreated one. Hence although the presence of alkali may aid the toxic action of the sulphide and polysulphides, these substances appear to have quite a definite toxic value in themselves.

This toxicity explains the immediate killing action of sprays containing sulphides and polysulphides; it does not, however, explain the continued protective action which such sprays exhibit, because on exposure to air in a thin layer solutions of sulphides and polysulphides decompose with the deposition of sulphur. To demonstrate this, solutions of such strength as might be used for practical spraying were prepared of three different mixtures of sodium polysulphides, ammonium polysulphide and lime-sulphur. Thin layers of each solution were then poured into Petri dishes and allowed to stand exposed to air. Sulphur began to be deposited in all cases in a very short time, and after varying intervals, in no case greater than 24 hours, the solutions became colourless and, after filtering off the sulphur, were found to give no reaction with sodium nitro-

prussiate, *i.e.*, were free from sulphide or polysulphide. The experiment was repeated by covering apple foliage with the solutions and, on the following day, washing the leaves and testing the liquid for sulphides. None were found. The same result was obtained whether the foliage was allowed to dry or kept in a moist atmosphere. It is therefore evident that any fungicidal value which polysulphide sprays possess a short time after spraying cannot be due to direct toxic action of the polysulphides themselves and must reside in the deposited sulphur itself, since none of the other insoluble products of decomposition are of a toxic character.

Differing Degrees of Sensitiveness to Sulphur among Fungi.—Sulphur itself is a solid, very insoluble in water and therefore it was impossible to test its toxicity by immersing spores in a solution of it. The most obvious way of finding out whether sulphur possessed any fungicidal properties or not, was to germinate fungus spores in hanging drops of water containing particles of sulphur. The fungus spores used for such tests necessarily required to be able to germinate normally in distilled water and after cultural tests the fungi given below were selected. The hanging drops of the sterile distilled water were first inoculated and precipitated sulphur washed free from acid added until the outside film of the drop was completely covered. Germination was noted after 24 hours. It was seen that there was a considerable difference in the action of the various fungi towards sulphur, some fungi such as *Sclerotinia fructigena* and *Phragmidium sub-corticum*, being completely inhibited from germination, others such as *Fusicladium dendriticum*, *F. pyrinum* and *Cladosporium fulvum* being partially inhibited, and others such as *Nectria ditissima*, *Botrytis cinerea* and *Verticillium sp.* being totally unaffected. A method was subsequently devised for estimating the effect of sulphur on the various fungi and by it the following figures were obtained: *S. fructigena* 100% inhibition, *C. fulvum* 50%, *N. ditissima*, *B. cinerea* and *Verticillium sp.* all 0%.

The difference in behaviour of the different fungi agrees with the experience of practical men, who find that although sulphur sprays are extremely useful against some diseases, such as scab and mildews, against others such as *Phytophthora*, they have no apparent effect.

Reaction of Fungal Secretions. A possible explanation of the difference in the effect of sulphur on fungi was that the acidity or alkalinity of the fungal secretions might be the vital factor in the fungicidal process. The reactions of a number of fungi sensitive to sulphur, and also of a number not affected by sulphur were therefore determined by growing them on media containing an indicator. The results were as follows: *S. fructigena*, *C. fulvum*, *B. cinerea*, and *R. niger* gave acid reactions, whilst *N. ditissima*, *Pyronema sp.*, *Alternaria sp.*, *Verticillium sp.*, *F. dendriticum* and *F. pyrinum* gave

alkaline reactions. The intensity of the reaction of the fungal secretions varied very much among organisms of like reactions; for instance *F. dendriticum* and *F. pyrinum* appeared to give much weaker alkaline reactions than such a type as *Pyronema*. The method did not, however, permit of any fine distinctions being made. It was remarkable that none of the fungi examined gave a neutral reaction, although it may be added that in one case of an unknown fungus producing only sterile mycelium in culture, the litmus used as an indicator in the medium on which it was grown was completely bleached by the fungus and the medium reverted to its original colour once more. From these experiments therefore, it appeared that fungi susceptible to sulphur included both acid and alkali secreting organisms, whilst on the other hand non-sensitive types also included acid and alkaline producers. It was quite evident therefore that the reaction of the secretions of the fungi had no correlation with their susceptibility to sulphur.

How does the Sulphur act?—Having ascertained that sulphur itself acts as a fungicidal agent the next question to solve was whether sulphur, as such, or whether some other product, gaseous or otherwise, which might be derived from it, is really the toxic principle. It was therefore necessary to consider the possible compounds which might be produced and to investigate their fungicidal properties.

In opening up the work in this direction the fact that sulphur can act fungicidally at a distance as well as when in suspension in water had to be kept in mind. The toxic agent, therefore, if not a gaseous substance might at least be presumed to be volatile. An extensive series of experiments was carried out to ascertain if any emanations from sulphur could be detected. In the course of these experiments sulphur in various forms was tested, including flowers of sulphur, plastic sulphur, precipitated sulphur, and sulphur prepared by the interaction of sulphur dioxide and sulphuretted hydrogen. The results generally were similar for all forms. On account of its convenience and fine state of division precipitated sulphur was ultimately used almost exclusively in the later stages of the work.

Since sulphur is apparently more active fungicidally at a relatively high temperature and in sunlight, and since also sulphur dioxide, and sulphuretted hydrogen had been suggested by previous workers as possible products responsible for its action, the first experiment consisted in exposing moistened sulphur in a warm greenhouse to sunlight, collecting the liquid which drained away and testing its effect on the germination of fungus spores. No inhibitory action was observed. It was noted, however, that filter paper strips moistened with a mixture of potassium iodide and starch solutions gave the characteristic blue coloration denoting the liberation of iodine when suspended close to the sulphur. This test is somewhat

unreliable on account of the decomposition of the iodide which gradually takes place independent of sulphur action, but the difference in colour between such papers suspended above sulphur and control papers under similar conditions, but beyond the range of sulphur was pronounced and afforded *prima facie*, evidence of action of some kind due to the near presence of sulphur. It was also found that the drainage liquid referred to liberated iodine from the iodide. Papers moistened with lead acetate under similar conditions gave no sign of any blackening: and the absence of sulphuretted hydrogen in readily detectable quantities was thus demonstrated. The absence of any bleaching effect on filter paper moistened with potassium bichromate indicated the absence of sulphur dioxide in amount sufficient for toxic effect.

Sulphur placed directly on filter papers moistened with potassium iodide and starch, lead acetate, and potassium bichromate respectively gave corresponding results. The coloration which developed under these conditions on the iodide-starch paper was particularly marked in a zone an inch or more away from the nearest part of the sulphur patch.

There being thus some evidence of a volatile substance originating from the sulphur another experiment designed to reproduce under laboratory conditions, the greenhouse hot-water-pipe method of sulphur application was tried. Sulphur was painted on the surface of a coil of metal piping through which was circulated a stream of hot water at a temperature not exceeding 80°C . A bell jar was placed over the coil and a current of air drawn through it. The air after passing through the jar was drawn through a solution of potassium permanganate. Strips of filter paper moistened with the three chemicals used in the previous experiments were also suspended in the bell jar. The results in the latter cases were the same as before. The permanganate solution was gradually decolorised, and after a few hours the purple colour had entirely disappeared, and a brownish deposit had been formed. No corresponding action occurred in a control flask of permanganate solution through which the air of the laboratory was drawn simultaneously.

The conclusion suggested by these results was that volatalised sulphur or a chemically active volatile substance of a reducing character was being given off from the sulphured pipes. The only two substances of the latter character which appeared in any way likely were ozone and hydrogen peroxide. The formation of the former could not be established by the tests applied, but evidence pointing to the latter was obtained when it was found that sulphur washed with distilled water, especially when the latter was just acidulated with sulphuric acid, gave up to the liquid a substance which liberated iodine from potassium iodide in the presence of ferrous sulphate. This test is given in the text books

as being produced only by hydrogen peroxide. A confirmatory test for the latter substance, viz., its action with titanium oxide dissolved in sulphuric acid was then applied, but it failed absolutely. This result appeared definitely to rule out the production of hydrogen peroxide, and ultimately it was found that the iodine liberation from the iodide in the presence of ferrous sulphate could be attributed to the presence of ferric iron which was discovered in appreciable quantities as an impurity in all the samples of sulphur examined. Up to this point the sulphur used had not been specially purified other than by washing with water, but subsequently more elaborate methods were regularly adopted. The greatest difficulty, however, was experienced in the preparation of an iron-free sample. The elimination of hydrogen peroxide from the list of possibilities in connection with the action of sulphur at a distance, appears to exhaust the conceivable alternatives to sulphur itself, and leaves one faced with the conclusion that in some manner sulphur can be distributed through air in a form which is highly toxic to certain fungi.

The following experiment supported this conclusion. Moist sulphur in a flask was exposed to a slow current of air which was subsequently passed through a wash bottle in which hydrogen was being generated by the action of sulphuric acid on zinc. Before passing into this wash bottle the air contained no sulphuretted hydrogen, but after exposure to hydrogen appreciable quantities of that body were detected, thus showing that sulphur in some volatile form was conveyed by the air into the wash bottle.

Evidence of a biological character was also secured to demonstrate that to none of the above mentioned possible products of sulphur action can the toxic results of sulphur treatment be attributed. The following details show that the quantity of any of the individual substances necessary for fungicidal effect is relatively so large that recognition by chemical tests would be easy and free from all possible doubt.

Toxicity of possible Products from Sulphur.—

Sulphuretted hydrogen.—The action of this gas on fungi does not appear to have been the subject of special investigation. Foreman stated in his paper that the gas had no effect on the germination of the spores of *B. cinerea*. Hanging drops of water saturated with the gas placed on the underside of the cover of a Petri dish containing water gave excellent germination, but repeat experiments in a Van Tiegham's cell, where the atmosphere was confined, gave different results. With *S. fructigena*, the highest concentration in which germination was observed to take place was .002%, but in some cases a solution of .0006% strength did not give successful germina-

tion. In these very dilute solutions, however, there was a great tendency for sulphur to be deposited, and the strength of the solution to be correspondingly reduced.

Sulphur Dioxide.—This gas is another product which is frequently derived from sulphur. Petri dish experiments of the germination of *N. ditissima* in hanging drops of a saturated and a 1/10 saturated solution gave no germination, whilst 1/100 saturated solution gave very good germination. Closed ring experiments, however, gave as limits .005% and .0005% for *S. fructigena*, *F. dendriticum*, *F. pyrinum*, *B. cinerea* and *N. ditissima*. Bourcart mentions that sulphurous acid cannot be used to destroy fungi.

Sulphuric Acid.—The strengths required to bring about the inhibition of germination varied slightly with the different species which variation, however, was not correlated with the sensitiveness to sulphur. The limits for *S. fructigena* were .05% and .01% for *F. dendriticum* .01% and .005%, for *F. pyrinum* .005% and .001%, for *B. cinerea* .01% and .01%, and for *N. ditissima* .005% and .001%. Bourcart states that 0.5% exerts a corrosive action on fungi, but that in practice much stronger acid must be used to ensure the destruction of the spores and mycelium.

Hydrogen Peroxide.—This substance might possibly be formed as the result of the catalytic action of sulphur. Experiments made to determine the limits of germination in solutions of this substance showed that there was no difference in its action on the five fungi used, the limits being .03% and .003%.

Caustic Soda.—This substance, whilst not being a possible product from sulphur, was investigated on account of its being a constituent of the spray film left by the lime sulphur spray fluid. The limits for the five fungi used were .05% and .01%.

Impurities of Sulphur.

(a) *Ferrous Hydroxide*.—Hanging drops of water were inoculated with spores of *S. fructigena* and ferrous hydroxide added. The resulting germination was excellent and showed that this impurity did not act as a fungicidal agent.

(b) *Calcium Sulphate*.—This was another impurity of the sulphur which had no deterrent effect on the germination of *S. fructigena*.

The conclusion from these experiments was that none of the compounds which might possibly be derived from sulphur would account for its toxic action.

Toxicity of Sulphur Washings.—Having eliminated the chemical products arising normally from sulphur, from the possible substances upon which the fungicidal property depends, we are forced again to consider the action of sulphur itself. A point which obviously required investigation was to find out whether the fungicidal action of sulphur depended on its solubility in water. The custom of placing a piece of sulphur in the drinking water of dogs, especially during periods when they are liable to attacks of distemper, gave some weight to the view that the minute amount of sulphur soluble in water was sufficient to act as an antiseptic. In order to determine the point, a number of hanging drops cultures were inoculated with conidia of *S. fructigena*, the medium of the drops being water in which sulphur had been boiled or allowed to stand for some time, all particles of sulphur being carefully filtered off from the liquid before use. Control hanging drops of spores taken from the same culture as in the case of the experimental drops were made in each case. Eight series of experiments were made and the results were similar throughout. Excellent germination took place in the sulphur washing as well as in the control drops. The trace of sulphur which is soluble in water does not appear to be sufficient to act fungicidally.

The Sphere of Influence of Sulphur Particles.—A point of great interest then arose as to whether absolute contact between the sulphur particles and the spore was necessary in order to bring about the death of the latter. The importance of this question lies not only in its purely scientific interest but also in its bearing on practical methods of spraying. If sulphur could kill off spores at a considerable distance the extreme care to secure a thorough spraying would not seem to be so necessary.

The following simple and convenient method of demonstrating the fungicidal action of sulphur was therefore devised with a view to testing how far the influence of the sulphur might be felt by the fungus spores. Sterile Petri dishes were poured with pure agar and allowed to cool. They were then inoculated with the spores of the fungus to be tested, the spores being distributed over the agar as evenly as possible by means of a spreader consisting of a sterilised glass rod, the end of which was bent at right angles. The plates were then examined under a microscope and small masses of moistened sulphur were superposed at convenient places. The plates were then incubated at 25°C. for 24 hours. The results showed very clearly the fungicidal action of sulphur. In the case of *S. fructigena*, there were well defined zones round the masses of sulphur within which no germination took place, and these zones merged more or less gradually with the area of normal germination outside the influence of the sulphur. Spores in contact with the sulphur frequently appeared to be dead, their contents brown and coagulated, whilst the majority within the inhibited zone were

manifestly unhealthy. Of the other susceptible fungi, only *C. fulvum* has been examined by this method, and this fungus proved not nearly so sensitive as *S. fructigena*, the spores frequently germinating when surrounded by particles of sulphur, although the length of such germ tubes in such cases were decidedly less than normal. *N. ditissima*, *Verticillium* sp. and *B. cinerea* were totally unaffected by the presence of sulphur.

By using this method, it was found that the width of the zone of inhibition of *S. fructigena* was influenced by the size of the sulphur mass, the concentration of the spores and the temperature of incubation. The inhibiting effect of a large mass of sulphur extended over a much greater range than a small mass, other things being equal. Further, when spores were crowded together, the zone of inhibition was perceptibly less than with smaller numbers. The influence of spore numbers was also seen in the germination of clumps of spores in zones where individual spores were completely inhibited. The third factor of temperature was much more difficult to distinguish and was often totally masked by the other factors. Generally, speaking, however, it appeared that a high temperature, about 25°C., produced a wider zone of inhibition than the normal room temperature.

From the above experiments one gathers that direct contact between the spores and the sulphur particles was not necessary to bring about the prevention of germination. That the sphere of influence of the sulphur particles was, however, of very limited extent was evident from the following experiment. A hanging drop of sterile water was impregnated with spores of *S. fructigena*. The spores of this fungus were usually rather dry, and when applied to a drop remained on the outside film, but in this experiment a small number were wetted by stirring up the drop with a platinum wire. Dry precipitated sulphur was then added to the outside of the drop very cautiously. After twenty-four hours incubation the spores on the outside of the drop, and consequently in contact or close proximity to the sulphur, had not germinated at all, whilst a few clumps of spores which had remained suspended in the centre of the drop, and consequently not near any sulphur particles, had germinated quite well.

A further series of experiments was made as follows, with the object of testing the existence of the sphere of influence of the sulphur particles by another method. Strips of sterile filter paper were supported on rings in Petri dishes containing water, the ends of the filter paper dipping in the water. In this way the filter paper was kept constantly moist. Each experiment required three pieces of filter paper. On the first, a small mass of moistened sulphur, impregnated with spores, was placed in the centre of the strip. On the second, a mass of moistened but non-impregnated sulphur was

similarly placed and on the reverse side of the filter paper, immediately opposite the sulphur, a drop of water containing spores was added. To the third strip of filter paper, a drop of the same suspension of spores as used on the second strip was applied but no sulphur was added. The Petri dishes were covered with moistened filter paper on the inside of the lids, and were incubated for twenty-four hours at 25°C. The results of the germination of the spores in contact with sulphur completely confirmed those previously obtained. *S. fructigena*, *F. dendriticum*, *F. pyrinum* gave no germination whatever in contact with the sulphur, whilst *N. ditissima* and *B. cinerea* grew normally. In the experiments in which the spores were separated from the sulphur by the filter paper germination was usually inhibited with the sensitive types, but the results were not so definite as with the agar plate experiments, a certain number of germinations, especially of clumps of spores, being often found.

The interpretation of these results appears to be that, whilst absolute contact between the spore and the sulphur is not necessary to bring about inhibition, no action will take place unless the sulphur comes within a certain minimum radius of action.

Action of Fungal Secretions on Sulphur.—The action of sulphur at a distance, as shown by the agar plate experiments described above, may be explained by the solution of the sulphur or by the formation of some soluble toxic product from the sulphur. This may be brought about either by the action of the fungal secretions or by the action of the agar on the sulphur. The first hypothesis was tested as follows. In making slope cultures by adding drops of the higher polysulphide of sodium solution containing spores to tubes of malt extract gelatine it was noticed that, after allowing the medium to solidify thoroughly, a slight milky precipitate could sometimes be observed. This precipitate was probably sulphur. Tubes of malt extract gelatine were therefore melted, and a drop of sodium polysulphide solution added to each tube, which was then sloped. After 24 hours those exhibiting a cloudy appearance were selected for use. If the tubes were well shaken and the polysulphide thoroughly mixed up with the medium, the deposition of sulphur did not take place, whereas if the tubes were not shaken after adding the polysulphide, the precipitate of sulphur was usually readily obtained. The fungi used for inoculation were *S. fructigena*, *F. dendriticum*, *F. pyrinum*, *N. ditissima* and *B. cinerea*. In the case of each fungus a cleared zone was formed round the fungus colony, and presumably was brought about by the solution of the sulphur by the secretion. Trials were made of adding pure precipitated sulphur to the medium, but the sulphur could not be distributed nearly so evenly as when deposited from the polysulphide and the method did not yield any success.

The Solution of Sulphur by Agar.—Whilst the solvent action

of fungal secretions may explain the zone of inhibited germination round the sulphur particles, it does not rule out the possibility of the solution of the sulphur by the agar. There was no reason why both factors should not play a part simultaneously. The action of the agar on sulphur therefore was tested by cooking up agar with a small quantity of sulphur in an autoclave for about an hour and then filtering off the insoluble sulphur. The agar prepared in this way was distinctly yellowish in colour and when poured into plates could readily be distinguished from the non-sulphured agar by looking through the agar layer in a horizontal direction. Petri dishes were poured with pure agar and sulphured agar, and spores of *S. fructigena* were distributed over the surface by means of a spreader. After twenty-four hours' incubation at 25°C. the plates were examined, and the germination on the sulphured agar was by no means so good as the control. Later a certain amount of germination took place on the sulphured agar, which, however, exerted a decided inhibition on the fungus.

The conclusion to which these results lead therefore is that in the agar plate trials mentioned above both the secretion of the fungus and the solution of the sulphur by the agar may have and probably had something to do with the final result.

Action across an Air Space.—Whilst the above line of investigation was being pursued, another series of experiments was being carried out simultaneously, the results of which gave rather a different light on the subject. These experiments were concerned with the action of sulphur across an air space, and they may be briefly described as follows.

The first experiments made in this connection consisted in exposing spores of *N. ditissima*, *R. niger*, and *Cladosporium herbarum* to the action of air drawn over sulphur heated to about 60°C., and, after moistening them with malt extract, noting their germination. These trials were made quite early in the investigation and unfortunately the fungi used were probably not sensitive to sulphur. Also the tubing through which the vapours were passed was afterwards discovered to be much too narrow. The action of the sulphur was therefore purely negative, germination of the treated spores taking place normally. A second series of experiments, in which cultures of the same fungi were made on agar in inverted Petri dishes, the bottoms of which contained powdered sulphur, also gave negative results for the same reason.

Later on, however, when it had been found that *S. fructigena* was sensitive to sulphur, this fungus was used with the object of testing the same idea by a somewhat different method. Spores of the fungus were spread as evenly as possible over poured agar plates by means of a spreader. The Petri dishes were then inverted and two rings placed in the bottom of each. A cover glass was then placed

on each ring, one cover glass being covered evenly with sulphur, and the other with calcium carbonate, every care being taken to place the sulphur and carbonate as close as possible to the agar surface without actual contact being made. After incubation at 25°C. for 24 hours the plates were examined. In each case great inhibition of germination had taken place, both over the sulphur and over the calcium carbonate.

This result was thought to be due to the desiccating action of the powdered substances, and the experiment was repeated with two Petri dishes, using moistened sulphur and moistened calcium carbonate. After incubation, there was marked difference in the germination over the sulphur and that over the calcium carbonate. In the former case there was practically no germination whatever, except for one or two clumps of spores, whilst in the latter case excellent germination took place. The experiment was subsequently repeated using strips of moistened filter paper in place of the cover-slips, the ends of the filter paper dipping into water placed in the bottom of the Petri dishes, and also using moistened silica in place of calcium carbonate. Over the silica excellent germination took place, whilst over the sulphur great inhibition occurred. The influence of any desiccation effect was ruled out by the moist conditions under which the spores were germinated.

This action over an air space was so surprising that experiments were made, using in place of agar hanging drops of water containing spores of *S. fructigena* over moistened sulphur and silica. Of nine experiments, however, none showed any reliable difference from the controls.

In the above experiments in Petri dishes, the sulphur had been effective over a space of about 1/16 of an inch, and if these results were genuine, it would be reasonable to suppose that in a confined atmosphere, the sulphur would be able to act over a much greater distance. Ring cultures were therefore set up in which a layer of agar was placed on the cover glasses, the exposed surface of the agar being covered with spores of *S. fructigena*, and moistened sulphur or moistened silica was placed in the bottoms. After incubation at 25°C. for 24 hours, the cultures were examined under the microscope. These experiments gave results similar to those obtained in the Petri dish experiments, great inhibition taking place over the sulphur, and excellent germination over the silica.

Greenhouse Experiments.—The fungicidal action of volatilised sulphur has been known for some time amongst fruit growers, and it is their custom to fumigate their vineries against grape mildew either by putting sulphur on the hot water pipes or by a Campbell's vaporiser. In order to test the efficacy of this method of using sulphur, the following experiments were carried out in two greenhouses, the pipes of one being painted over with a mixture of sulphur and water,

the water evaporating and leaving the sulphur spread more or less evenly over the pipes. The host plant chosen for experiment was wheat and the fungus *Erysiphe graminis*.

In the first experiment, a large box of wheat, about five weeks old and heavily infected with mildew, was placed in the sulphured greenhouse, and a similar box left in the non-sulphured greenhouse as a control. Similar conditions of temperature and moisture were maintained in the two greenhouses as far as possible, although the temperature in the sulphured greenhouse was on an average somewhat higher than in the control. Three days after the commencement of the experiment, the patches of mildew on the wheat exposed to the sulphur fumes were slightly brown in colour and did not appear to be healthy. The young leaves also were distinctly less heavily attacked than before. Within nine days, this attack of mildew had practically subsided. The original patches of the fungus on the older leaves were coloured a deep brown, whilst the younger leaves, formed since the commencement of the experiment, showed no development of mildew whatever. The control box in the non-sulphured greenhouse, however, still remained very heavily attacked by the fungus.

For the second experiment, six boxes of wheat were grown and inoculated with *Erysiphe graminis* when about four weeks old. At the first definite signs of infection three of these boxes were transferred to the sulphured greenhouse and the other three left in the non-sulphured greenhouse. In the former case, the mildew was manifestly unhealthy in three days, and at the end of nine days the original patches were coloured a deep brown and could only be identified after careful searching. The controls meanwhile had developed an exceedingly vigorous attack of *Erysiphe graminis*.

The third experiment consisted of inoculating six healthy boxes of wheat seedlings with mildew, three boxes being placed in the sulphured greenhouse and three kept in the non-sulphured house. The method of inoculating merely consisted of spreading shoots heavily infected with mildew over the growing plants, a method which was found to answer very well. No infection resulted in the sulphured greenhouse, but a heavy attack developed on the wheat in the control boxes within nine days.

In the fourth experiment, two small pots of infected wheat seedlings were placed under each of two bell jars in the sulphured greenhouse. By means of tubing suitably arranged, a current of air was drawn through each bell jar, at approximately the same rate, but in one case the atmosphere of the greenhouse entered the bell jar, whilst in the other, the non-sulphured atmosphere from the adjoining room was allowed to enter, being conveyed to the jar through a long tube, which enabled the air to be warmed to the green-

house temperature before entering the bell jar. Ten c.cs. of water was given to each pot daily by means of tubes without removing the jars. The result of the first trial was very disappointing, the mildew in the sulphured as well as in the control bell jar continuing to grow most vigorously. Subsequent experiments under slightly modified conditions, which were found to be necessary in order to secure that a representative sample of the greenhouse atmosphere was provided to the pot subjected to its action, proved, however, that while the non-sulphured atmosphere had no detrimental action on the mildew the sulphured greenhouse atmosphere was highly toxic to it and caused obvious injury within twenty-four hours.

Further experiments have been carried out recently with the object of investigating the action of volatilised sulphur more closely and, as mentioned above, the details are shortly to be published.

FRUIT BREEDING INVESTIGATIONS.

BY B. T. P. BARKER AND G. T. SPINKS.

APPLES.—Investigations on apple breeding have now been carried on for a number of years. The crosses have been made either on pot trees in the orchard-house or on trees in the plantations, and in both cases the flowers used have been enclosed in transparent waterproof paper bags. In the case of varieties known or suspected to be self-fertile the flowers to be fertilized have previously been emasculated, but this operation has not been carried out on varieties known to be self-sterile. Pollination has usually been effected by touching the stigma of the female parent with ripe anthers obtained from the male parent. It is sometimes difficult to obtain ripe anthers at the right time if early and late-flowering varieties are to be crossed, and last year a cross was made with pollen which had been collected in a watch-glass and kept covered up in the laboratory at the ordinary temperature for a week. This pollen was then applied to the stigma with the tip of the finger and it was found that the set of fruit obtained, and the number of seeds it contained was as good as when fresh pollen was used. In numbers of instances no fruit was obtained when flowers were pollinated, but this was usually found to be due to the stigma not being in a receptive state when it was pollinated or to the pollen being poor. No definite cases of incompatibility of crossing between any varieties have been observed, nor has it been found that any varieties are distinctly good or bad for pollinating certain other varieties. Numbers of varieties have been self-pollinated and the degree of self-fertility found has usually corresponded with that given in other observers' lists of self-fertile and self-sterile apples. Langley Pippin, however, appears to be slightly self-fertile, while it is usually described as self-sterile. William Crump and Edward VII. appear to be self-sterile. Occasionally flowers which have been either selfed or cross-pollinated set fruit which matures normally but is found to contain no seeds; this seems to be specially common with Lord Suffield.

The following list shows the various crosses which have been made and from which seedlings have been or are being raised. Crosses which produced no fruit or from which only one or two

seedlings have been raised are not included in the list. In each case the female parent is placed first.

Allington Pippin × Ben's Red	Court Pendu Plat × Lord Derby
Ditto × Cox's Orange Pippin	Ditto × Peasgood's Nonsuch
Ditto × Lord Hindlip	Ditto × Wellington
Ditto × Red Astrachan	Ditto × Worcester Pearmain
Ditto × Star of Devon	Cox's Orange Pippin × American
Ditto × Worcester Pearmain	Mother
American Mother × Cox's Orange	Ditto × King of the Pippins
Pippin	Ditto × Red Astrachan
Annie Elizabeth × Cox's Orange	Ditto × Sturmer Pippin
Pippin	Ditto × Wellington
Ditto × Lord Derby	Ditto × Worcester Pearmain
Bismarck × Allington Pippin	Cox's Pomona × Langley Pippin
Ditto × Bramley's Seedling	Dabinett × Sweet Alford
Ditto × Emperor Alexander	Devonshire Quarrenden × Allington
Ditto × Hollandbury	Gascoigne's Scarlet × Encore
Ditto × Jonathan	Hollandbury × Bismarck
Ditto × Newton Wonder	Ditto × Emperor Alexander
Ditto × Wellington	Jonathan × Bismarck
Court Pendu Plat × Allington Pippin	Lane's Prince Albert × Cox's Orange
Ditto × Blenheim Orange	Pippin
Ditto × Charles Ross	Ditto × Wellington
Ditto × Cox's Orange Pippin	Langley Pippin × William Crump
Ditto × Dabinett	Lord Derby × Bismarck
Ditto × Golden Noble	Medaille d'Or × Chisel Jersey
Ditto × James Grieve	Ditto × Kingston Black
Ditto × King of the Pippins	Ditto × Strawberry Norman
Ditto × Kingston Black	
Newton Wonder × Cox's Orange	Royal Jubilee × Wellington
Pippin	Sturmer Pippin × Cox's Orange
Ditto × Lord Derby	Pippin
Ditto × Queen	Wellington × Newton Wonder
Queen × Allington Pippin	Worcester Pearmain × James Grieve
Ditto × Cox's Orange Pippin	Ditto × Sturmer Pippin
Red Astrachan × Allington Pippin	(Medaille d'Or × Kingston Black)
Ditto × Jonathan	× Royal Jubilee
Ribston Pippin × Red Astrachan	

Some of these crosses were made with the object only of seeing the result of crossing varieties of widely different character, while others were made with the object of trying to obtain combinations of definite characters. Large numbers of seedlings have also been raised from seed obtained from various apples without any cross having been made, and in these cases, of course, the male parent of the seedling is unknown. It was thought that by this means an idea would be obtained of the characters transmitted to its offspring by the one known parent, and the knowledge thus gained could be used when selecting parents with which to make definite crosses. Seedlings of this kind have been raised from seed of Allington Pippin, American Mother, Ashmead Kernel, Bismarck, Charles Ross, Cox's Orange Pippin, Dabinett, James Grieve, Jonathan, King of the Pippins, Red Astrachan, Reinette Obry, Rival, Sweet Alford, and William Crump. During the last season seed has also been saved from many other varieties with a view to raising more seedlings, and it is hoped to raise about 50 seedlings of each of the varieties

selected, these including all the varieties which are thought likely to be useful for breeding purposes.

Apple seeds are rather uncertain in germination, especially if they have been allowed to get too dry, and will sometimes remain in the soil for two years or more before germinating. It has been found that they usually germinate well the first year if they are placed in moist sand when they are removed from the apples and kept there until about March, when they are sown in seed boxes. The young seedlings are transferred to pots and then, when they are large enough, to nursery beds in the open. The seedlings are just pruned sufficiently to give them the framework of a bush, and are then allowed to remain unpruned in order to bring them to a fruiting condition as soon as possible. Scions are also taken from these seedlings and worked on Paradise stocks in order to obtain several trees from the same original seedling. In future it is intended to work these scions on one of the types of Paradise stock which induce very early fruiting, and in this way it is hoped to obtain fruit of the seedlings in the shortest possible space of time. But it is not yet known how far this endeavour to obtain early cropping will be successful, for seedlings do not naturally produce fruit, nor even attain the habit and foliage of their mature years until a number of years have elapsed, and it is doubtful whether the use of a "precocious" stock will shorten the period of "infancy" during which it seems to be impossible for a seedling to bear fruit.

Apple-breeding is naturally a very slow process, and it is only two or three years since the seedlings of crosses made in 1909 first bore any fruit, and not until this last season have any of them borne a good crop. At present the only cross about which much can be said is that between *Medaille d'Or* and *Kingston Black*, two cider apples, the former a bitter-sweet with a yellow russet skin, the latter an apple of medium acidity with a very dark red smooth skin. There is considerable variation between the different seedlings and no marked dominance of any character has been found. Such characters as habit of growth, type of foliage, habit of bearing, susceptibility to disease, and the various characteristics of the fruit sometimes resemble more closely one parent, sometimes the other; while in some cases they are intermediate or show very little resemblance to either parent. Some of the trees have very evidently inherited the *Kingston Black* susceptibility to canker, while others are free from this disease; and some trees show plainly the *Medaille d'Or* habit of bearing, a heavy crop of fruit being borne in thick clusters along the length of the branches. Trees from 14 seedlings of this cross have now borne fruit, and, judging only from the observations of one season, it may be said that the fruits show wide differences. Without at this stage going into details it may be noted that the fruits, as regards appearance, texture, and sugar, acid, and tannin

content, exhibit almost every gradation between the two parent types. When the cross between the parents was made the seeds from the different individual fruits were kept in separate batches, and it is now interesting to find that the seedlings derived from each particular fruit have a distinctly closer resemblance to each other than to those obtained from another fruit. The same feature has been noted with strawberries.

Some seedlings from the cross Cox's Orange Pippin $\times$ King of the Pippins have now commenced to bear, but so far only four seedlings have borne crops, and it is therefore impossible to draw many conclusions as to the inheritance of various characters; but the fruit of one or two of the seedlings seems promising and may possibly have some commercial value.

PLUMS AND CHERRIES.—Only a small number of crosses have been made with plums and no seedlings have as yet arrived at the fruiting stage. The following list, however, shows the crosses which have been made:—

Coe's Golden Drop $\times$ Merryweather Damson	Merryweather Damson $\times$ Coe's Golden Drop
Cox's Emperor $\times$ McLaughlin's Gage	Prince Englebert selfed
Heron $\times$ McLaughlin's Gage	Victoria $\times$ Pershore
McLaughlin's Gage $\times$ Winesour	Winesour $\times$ McLaughlin's Gage

Of these varieties Prince Englebert and Merryweather Damson were found to be self-fertile, while Curlew, McLaughlin's Gage, Cox's Emperor, and Coe's Golden Drop appeared to be self-sterile.

Numbers of seedlings are also being raised, as in the case of apples, from seeds of chance-fertilized plums, a number of varieties having been selected so as to include the best examples of each type of plum.

The following crosses have also been made with cherries:—

Guigne d'Anonnay $\times$ Bigarreau Napoleon	Early Rivers $\times$ Bigarreau Napoleon Bigarreau Napoleon $\times$ Early Rivers
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All these varieties of cherries were found to be self-sterile.

CURRENTS AND GOOSEBERRIES.—A large number of seedlings of black and red currants and gooseberries have been raised, and a further batch will be raised next year. These seedlings have been grown from seed which is partly the result of definite crosses, partly obtained by selfing, and partly of known female parentage only. The main object in growing these seedlings is to obtain new varieties of real commercial value, and with this object in view the best of the seedlings are being selected, attention being paid to such points as season, crop, size, appearance, firmness and flavour of the fruit, and vigour of growth and disease resistance of the bush. It is thought that observation of the seedlings for three years after they start to bear fruit will enable us to select any which show promise, and the remainder will then be discarded. Seedlings

which appear promising are being propagated by cuttings so as to give them a further trial on a larger scale ; these again will be subjected to a process of selection and finally only the very best will be retained. The large number of seeds obtained from a single cross, and the comparatively short time in which they will produce bushes bearing a crop enables much more rapid progress to be made with these fruits than with apples and plums. Probably a succession of seedlings will be raised for some years, so that as some of the older ones are discarded as useless their places will be taken by fresh seedlings for trial. At the same time, as far as is practicable when dealing with large numbers of seedlings, the characters of individual plants are being noted in order to gain some knowledge of the way in which various desirable and undesirable characters are inherited. Such information should be valuable when attempts are made by crossing to combine in one plant various desirable characters.

All the foregoing remarks apply also to raspberries, strawberries and other soft fruits, with which work is being carried out on similar lines.

The following crosses and selfs have been made with currants and gooseberries :—

BLACK CURRANTS.

Boskoop selfed
Baldwin selfed
Black Naples × Baldwin
Ditto × Boskoop
Ogden's Black selfed
Ditto × Black Naples
Ditto × Baldwin
Ditto × Boskoop
Ditto selfed

RED CURRANTS.

Raby Castle selfed
Ditto × Fay's Prolific

RED CURRANTS

Raby Castle × Fay's Best
Fay's Prolific selfed

GOOSEBERRIES.

Whitesmith × Whinham's Industry
Ditto × Keepsake
Careless × Keepsake
Ditto × May Duke
Whinham's Industry × Muttons
Keepsake × Muttons
Telegraph selfed
Mitre selfed
High Sheriff selfed

The crosses and selfs were made on bushes in pots in the orchard-house, the flowers used being enclosed in paper bags. All these varieties of *Ribes* are self-fertile and flowers which were cross-pollinated were, therefore, previously emasculated.

Seedlings of unknown male parentage have also been raised from seed of Boskoops, Ogden's Black, Raby Castle, Fay's Prolific, Keepsake, Gretna Green and Fruheste von Neuwed.

Muttons is a gooseberry from Devon, said to be immune to attacks of American Mildew, but we have no real proof that it is so. It has never shown any signs of mildew in our plantations, but this is merely negative evidence since mildew rarely appears on any variety here.

Some of the above seedlings have already fruited for several years and the best of them are being propagated, but very many of them have not yet reached the fruiting stage.

RASPBERRIES.—The following crosses and selfs have been made with raspberries and other members of the genus *Rubus*.—

Alexandra Autumnal × Bath's Perfection	Loganberry × Bath's Perfection
Ditto × Harzuweil	Ditto × King's Acre Berry
Ditto × Schaffer's Colossal	Ditto × Laxton Berry
German Everbearing × Loganberry	Ditto × Rubus Biflorus
Ditto × King's Acre Berry	Ditto selfed
Ditto × Superlative	Lucretia Blackberry × Bath's Perfection
Hailsham Berry × Himalaya Brery	November Abundance × Superlative
Himalaya Berry selfed	

These crosses and selfs were made on plants either in the open or in the orchard-house, the flowers used being protected by paper bags. It was necessary to emasculate flowers before crossing, as all these varieties are self-fertile.

Most of the seedlings fruited last year and a few of them the previous year also. Some promise to be very good.

The crosses between different varieties of raspberry have usually produced very vigorous seedlings, some of which bear heavy crops. The Alexandra Autumnal crosses are mainly mid-season or late in fruiting, while about 10% of them are autumn-fruiters. The canes have all been treated as summer-fruiters and in some cases the old canes have borne fruit, and there has also been a good crop of autumn fruit near the tips of the young shoots; in other cases only autumn fruit has appeared. There is much variation in the size, flavour and firmness of the fruit, and the size of the crop. The cross with Schaffer's Colossal has produced plants about 10% of which bear fruit with the dark colour of the male parent, while out of 60 of the Bath's Perfection crosses four bear yellow fruit.

There are only a few plants from the German Everbearing and Superlative cross, but the majority of them are late summer or autumn fruiters, and the large and rather loose character of the berry of the German Everbearing has been inherited by most of them. The crosses with Loganberry and King's Acre Berry are vigorous in growth, but are almost sterile, often bearing few flowers, or at all events producing few fruits, which are usually very small and consist of only a few drupelets. Self-pollination of the Loganberry cross showed it to be self-sterile. The cross with the King's Acre Berry resulted in plants whose vegetative characters bear a close resemblance to those of the King's Acre Berry.

November Abundance also transmitted the quality of late or autumn fruiting to most of its offspring, and most of the fruits were loose and consisted of comparatively few, and often large, drupelets.

The Loganberry crosses have all produced vigorous plants which are almost sterile, the cross with *Rubus biflorus* being apparently quite sterile. That with the King's Acre Berry resembles the male parent in its canes and leaves. The Loganberry selfs show a good

deal of variation, though nothing very striking. The chief differences are in the season of fruiting, size of crop, and size of fruit, and the best canes are being noted, and after observation for another year or two will be propagated if they seem worth it. Several seedlings bear fruit which is markedly less pubescent than usual, so that the fruit is very shiny compared with an ordinary Loganberry.

Very few Hailsham $\times$ Himalaya seedlings have been raised, and they are interesting chiefly on account of the different types of cane and leaf which have appeared. Some of them are partially sterile, but such fruits as have grown are very similar to the Himalaya berry. The Himalaya berry when selfed has apparently bred true, the seedlings being exactly like the parent.

Lucretia crossed by Bath's Perfection has given a number of vigorous plants all very similar to the Lucretia in foliage and habit of growth. Many of them have borne no flowers and those which bore flowers produced very poor fruit, which was somewhat similar to the berry of the Lucretia.

Several other blackberries were also crossed with raspberries, but very few seedlings were raised, and they have also been mixed so that their parentage is now unknown. But in every case the plants are of a pronounced blackberry type, though they all appear to be sterile, none of them having yet formed either flowers or fruit. A large number of plants from seed of chance-pollinated Loganberries have yielded nothing of interest. Similar seedlings from a yellow blackberry have all borne black fruit of poor quality.

The results obtained from the above crosses suggest that nothing useful is likely to be obtained by crossing different species of *Rubus*, as the resulting plants are so often almost or entirely sterile. It is, of course, possible that seed obtained from these F_1 plants might produce more useful plants in the F_2 generation, and where possible such seed has been saved and a second generation of seedlings will be raised from it. On the other hand crosses between different commercial varieties of the same species promise to produce new varieties with good qualities as regards size, flavour, and cropping power, and, as might be expected, the products of these crosses are often very vigorous in growth. Further crosses and selfs with other good varieties will be made in the future.

STRAWBERRIES.—Large numbers of seedlings have been raised from crosses and selfs, and as fruit can be obtained from a seedling two years after the cross was made results can be obtained fairly quickly, and the work with strawberries is on that account further advanced than with any other fruit. Unfortunately, war conditions, the occupation of the staff with war-work, and the shortage

of labour, have resulted in large numbers of the seedlings being lost, but the work is now being carried on normally again and a considerable number of records are available.

The following crosses and selfs have been made :—

Admiral selfed	President × Count
Bountiful selfed	Ditto × Sir J. Paxton
Count selfed	Queen selfed
Ditto × President	Ditto × Admiral
Duke selfed	Ditto × Maincrop
Earl selfed	Ditto × Reliance
Ditto × Vicomtesse	Ditto × Unique
Everbearing selfed	Reliance selfed
George Munro × Royal Sovereign	Reward selfed
Givon's Late × Leader	Royal Sovereign selfed
Ditto × Louis Gauthier	Ditto × Monarch
Ditto × St. Antoine de Padoue	Ditto × St. Antoine
International selfed	Ditto × Vicomtesse
King George V. selfed	Sir J. Paxton selfed
Ditto × President	St. Antoine selfed
Laxton × President	Ditto × President
Leader selfed	Unique selfed
Ditto × Sir J. Paxton	Ditto × Count
Ditto × St. Antoine	Vicomtesse selfed
Louis Gauthier × Reward	Ditto × Earl
Maincrop selfed	Ditto × Royal Sovereign
New Epicure selfed	Waterloo × Louis Gauthier
New Pine × Reward	White Perpetual selfed
President selfed	

These crosses and selfs were made on plants in pots in the orchard-house, each pot being protected with a covering of muslin stretched over a wire framework and secured by an elastic band round the pot. All varieties were found to be self-fertile and it was therefore necessary to emasculate flowers before cross-pollinating them. It was found that the receptacle of an emasculated flower would never swell up to form a fruit unless it was stimulated by pollination.

Other crosses which have been made are not included in this list, because the resulting seedlings have been lost or because only very small numbers of seedlings have been raised. Many of the above crosses were only made last summer and therefore no seedlings from them have yet been raised. Observations on the fruiting seedlings have been directed mainly towards the selection of those which are noteworthy as regards cropping power, season, and quality of the fruit in various respects. The most promising seedlings are being propagated by runners for more extensive trials. In addition some general idea has already been obtained of the extent to which certain characters are inherited. Seedlings obtained by selfing, although they vary considerably, seldom show any striking differences from their parents. Certain qualities appear to be dominant when introduced into a cross; for instance, the size and typical texture of the fruit of Leader and the pale colour, softness and scent of Louis Gauthier. Distinct earliness or lateness of one parent is

usually reproduced in its offspring when the other parent is a mid-season variety. The fruit of a cross between two dark-coloured varieties, such as Vicomtesse and Earl, is usually dark in colour, while that of a cross between Vicomtesse and Royal Sovereign has the brighter colour of Royal Sovereign. A second generation is being raised by selfing the first generation plants obtained from certain crosses, but so far none of the F_2 plants have fruited. As noted in the case of apples, so with strawberries, it has been found that the plants obtained from the seeds of one particular fruit tend to resemble each other more closely than plants from other fruits of the same cross.

FACTORS GOVERNING FRUIT-BUD FORMATION.

BY B. T. P. BARKER AND A. H. LEES.

II.—THE NORMAL ANNUAL GROWTH OF THE APPLE AND PEAR.

In the Annual Report for 1916 the authors have set out their general view on the above subject and have also adduced certain evidence, largely meteorological, to prove their contentions. Owing to the lack of definite evidence on many sides of the subject hitherto it has been necessary often to use such phrases as "sap pressure," "organic food" and the like, and to keep the discussion on quite general lines. Though such general lines are unavoidable in presenting a subject on which ideas are still vague, it is not the desire or the intention of the authors to pursue the subject in that manner. Little by little it is hoped to bring definiteness into the picture and the attempts to do so will be embodied in a series of articles appearing under the same general title as the first article.

In growing fruit, as in any other branch of horticulture or agriculture, man seeks to modify nature. Sometimes he stimulates and sometimes modifies growth, but he always interferes with natural growth in some way or other if he tries to obtain a maximum crop. Nature seeks reproduction; man seeks food. The two aims are usually divergent. Now one cannot intelligently modify a process unless that process is known and known in detail. The first desideratum therefore in successful fruit culture is to study the normal growth of the fruit-bearing tree and this article is an endeavour to deal with the normal process of yearly growth as far as the facts and causes thereof are known. At first sight it might appear that a fruit tree such as an apple or pear is one single organism, but a far clearer picture of the processes involved may be obtained by treating each as a colony of competing units. Now one of the fundamentals of any living organism is its capability to grow, and the essence of growth consists of the power of increasing cell size, and of subsequent cell division. This power of increase and division is largely, though not entirely, concentrated in the

growing points situated in the buds. The bud, therefore, becomes the unit and the tree may be regarded as a colony of competing growing points connected by conducting and protective tissue. Each bud may be regarded as a unit seeking to go its own way, but always modified and influenced by the action of other and competing buds.

A tree differs from an annual plant in that it does not die at the end of the growing season. Part remains over the winter and starts again into active growth when spring comes. Its life history falls thus into yearly cycles, during each of which certain changes take place as conditions permit. The simplest way, therefore, of studying the growth of a tree is to start with the normal yearly growth, and the simplest case of this is the ordinary shoot produced, say, from the bud left as a terminal from the previous year. Now here there is nothing essentially differing from the behaviour of a vegetative shoot of an ordinary annual plant, and it is only when the behaviour of the buds on this shoot during the second growing season is considered that difficulties are encountered. It is at this point therefore, namely the behaviour of the buds on a wood twig of last year's growth, that this investigation begins.

Such a twig in winter shows a series of buds, each of which contains a growing point, dormant as yet, but fully capable of growth. At first no green is seen, but as the spring begins the first signs of the future leaves appear. The first question that suggests itself is what are the conditions that have called forth this growth. There are many reasons for supposing that it is a question of increasing air temperature. Thus if a shoot from a plant such as a vine or any other convenient climber be led through a window into a warm dwelling room in late winter the buds on the portion within the room begin to come out far earlier than those on shoots left outside. All questions of root action are eliminated in this case, since the early shoot remains connected with the roots and yet breaks into leaf earlier than its fellows in the cooler temperature outside. Again, shoots cut off a tree in late winter and placed with their cut ends in water in a warm room also come into leaf earlier than their fellows still attached to the parent tree. In this case again root action is eliminated, since the cuttings have no roots. Thirdly, if a large shoot be cut off a tree in spring when the buds are already shooting and allowed to lie on the ground, these buds will continue to grow for a certain time as long as food and moisture inside the twig remain sufficient.

These facts, therefore, indicate that the growing points of the buds are stimulated by rise of temperature and are independent of root action in this first stage of growth. It should, however, be pointed out that none of these effects can be produced, at any rate in so short a time, if the tree has not undergone a preliminary resting

period. The reason of this is not yet quite clear, and it is not intended here to enter on a discussion of its causes. The phenomenon is simply accepted for the time being as a fact.

First Stage of Growth.—That this first stage of growth is independent of root action may also be seen from the results of bud measurements of typical twigs carried out in 1918. Thus, in the case of a Vicar of Winkfield pear, growth was first measureable on March 14th, and continued fairly evenly from all the buds on the twig until April 12th. During this time the soil temperature varied between 7.8°C . and 8.4°C . (46° — 47°F), and the percentage of possible moisture in the soil between 85% and 95%. The soil was therefore both cold and wet, conditions which are known to hinder root action. So far the length of young leaf showing from the buds is about the same for all and constitutes what may be considered as the *first stage of growth*.

The conditions necessary to bring it about would appear therefore to be

- (a) A preliminary rest period, followed by
- (b) A rise in temperature.

Second Stage.—As the spring progresses the second stage of growth begins, a period that is marked by the fact that the terminal bud or buds gain precedence. The length of young leaf showing outside the bud scales increases at a greater rate than that of the buds near the base of the last year's twig. Though all the buds are growing, the apical buds grow faster than the basal. As growth continues, more and more of the young leaves become visible. At first they lie closely together in a bunch directed away from the twig, but later as growth increases they spread out away from each other forming a whorl of leaves that really represent a telescoped shoot. As growth increases still further the stem of the new twig becomes visible, and it is then possible to measure the length of the axis instead of merely the length of the young leaves as in the earlier stages. Actual measurements taken showed that the more basal buds were gradually ceasing to grow in length though the apical ones were still going ahead. As the end of this second stage the majority of the buds had stopped growth in length, having settled down to the condition of wood spurs of various lengths, while the apical to the number of about four were still in active growth.

The twig of last year's growth can then be divided into three portions :—

- (a) The apical region from which strong shoots are preceeding.
- (b) The large middle portion which had produced short wood spurs each of about equal length. These wood spurs

consist of a large terminal bud in a dormant condition (*i.e.*, covered by dark scale leaves), surrounded by 3—5 leaves.

- (c) A basal portion of about three to four buds, all dormant, but weak and surrounded with 0—3 leaves.

The above mentioned pear has been chosen as an example as it shows what is perhaps the simplest case. In apples the three regions are not so sharply differentiated, and the basal portion is often bare of obvious buds.

Now it is clear from these facts that some second growth factor has appeared which has stopped the growth of most of the buds while still allowing the four or so apical buds to continue. In ordinary gardening parlance the condition is explained by the phrase that the sap always seeks the top portions of the plant. If by sap is meant the liquid that passes upward through the wood (xylem) elements, then this theory has certainly never received any scientific proof. When looked at closely this explanation is in the nature of a description rather than a cause of results.

There must, however, be some reason and several might be suggested. Thus it might conceivably be connected with soil moisture. During the period involved from April 12th to May 14th, soil moisture decreased, but always remained above 60%, an amount ample for any possible root action. Soil temperature also shows a similar variation, but in the upward direction. In a word, conditions for root action were steadily increasing during this period, and yet a differentiating action appeared in the buds. Again the difference might be accounted for by slight original differences in the buds when in the winter stage. Such differences may be shown to exist, but as an explanation this is a failure since the same general order of events is observed whether a twig is unpruned, lightly, or hard pruned. In other words the behaviour of the buds in the second stage of growth does not depend on their original condition but on their position on the twig. Much light is thrown on the subject by some recent work done by Loeb. By working with specially favourable plants he was able to show that whether a non-terminal bud of a shoot grew or not depended on the influence of the terminal bud's leaves. Thus if a summer shoot of a willow be placed in a warm moist chamber after all the leaves have been removed it is the terminal bud which grows out and the terminal only. If all the leaves except the terminal be removed it is the second bud that grows out.

The first experiment may be explained on either of two hypotheses.

- (1) The first bud to grow takes the whole of some material necessary to growth and so starves the others. Or

- (2) The first bud to grow manufactures some inhibitory substance that flows backward and checks all the other buds.

Now if, after the second experiment has started and the sub-terminal bud is growing the terminal leaf is removed, the terminal bud begins to grow, soon outstripping the sub-terminal. Food substances do not therefore affect the issue, and the only other thinkable hypothesis is that of an inhibitory substance flowing downwards through the stem. Loeb has shown that both leaves and active buds appear to develop such a substance, and the hypothesis throws considerable light on the behaviour of fruit trees. Thus in the first stage when growth is slow there is not much of what may be called for short the "Loeb effect." But as the plant enters the second stage and temperature and sunlight increase the Loeb effect becomes more and more marked, till finally it is strong enough to bring most of the lateral buds to a standstill only allowing the three or four apical buds to continue growth.

This, therefore, suffices as a general explanation why certain buds stop growing at a time when growth conditions are fairly strong and are daily increasing in strength.

Third Stage of Growth.—This stage, which is the last, is marked by the fact that most of the buds have ceased growth, and only a few at the apex are elongating to form woody shoots. As general growth conditions become less favourable, either on account of deficient soil moisture, as happens frequently in summer, or of deficient temperature and light, as may happen in autumn, one by one the still active growing apical shoots come to a standstill. As one might expect from the Loeb effect, the terminal shoot is the last to stop. This condition may be illustrated from the measurements of 1918, where in the case of a King's Acre Pippin apple, the third subterminal had ceased growth on July 13th, the second and first subterminal on August 2nd, and the terminal on August 23rd.

Now if the Loeb effect were the only factor controlling the particular behaviour of the original buds under consideration at the end of the year the twig should show :—

- (1) A few wood shoots from the apex.
- (2) A series of wood spurs becoming weaker and weaker towards the base of the shoot.

While this is so, generally considered, the actual condition in detail varies somewhat. Thus the graduation in strength of the wood spurs is not perfectly even as one passes to the base of the shoot. Measurements show for instance that in the case of the Vicar of Winkfield shoot already considered the curve of declination is especially sharp near the base and (in other examples) extra strong wood spurs and occasionally shoots occur out of their expected position. There is therefore a bud factor occurring as well.

That there is variation in the constitution of buds may be shown such evidence as the following.

- (a) If the length of dormant buds on a last year's twig be measured in winter time it is found that the three or four near the base are markedly smaller than the rest. If length is a sign of strength then these buds are obviously weaker than normal, and under a given stimulus would make less growth than other longer ones.
- (b) From the rate of flow of water through the vascular tissue of buds in the dormant condition. In order to test whether buds were likely to receive a varying supply of crude sap from the main conducting tissue of the stem, shoots were taken in winter time and the cut ends placed in an apparatus so as to subject them to a considerable pressure of water. The buds, one at a time, were then carefully broken off, and the rate of flow through the tissue supplying the bud measured. The results on a number of twigs showed :—
 - (1) That in every case a few buds at the base showed very small flows.
 - (2) That buds near the apex showed sometimes abrupt variations, certain buds having a large flow compared with the normal.
 - (3) That the apical buds and especially the terminal usually showed large flows. An exception to this was the subterminal which always had a very weak flow.
 - (4) That there was a considerable variation in different varieties. For instance, in the apple Lord Hindlip no flow at all could be secured in any lateral bud but only in the terminal.

These results therefore supply one possible reason for the future behaviour of the buds. Thus (1) explains the great weakness of buds at the base of a twig and (2) the reason why certain of the lateral buds make a greater growth than is to be expected from their position on the twig, and the consequent subjection to the Loeb effect. The weakness of the shoot growing from the subterminal bud as explained by (3) and (4) offers one explanation of the different behaviour of different varieties of apples and pears.

- (c) From the effect of "ringing" and "nicking" in buds of last years shoots on planted trees.

For the full results the reader is referred to the article on this subject which follows below. The

main result bearing on the question under discussion was that, whenever a bud was completely cut off from any descending inhibitory substance it made growth in proportion to its original strength, and not in accordance with its position on the stem. In this way fairly strong wood growth could be obtained from basal buds though weaker of course than shoots obtained from higher buds.

- (d) From the behaviour of shoots kept in water in a warm place. When apple and pear twigs were kept in water in a greenhouse in early spring for experimental purposes, it was noticed that the apical two or three buds grew out first. Below these a large number of buds remained dormant until nearly the water level, where frequently one or two basal buds made an appreciable growth. The Loeb effect would explain why most of the buds failed to grow but not why the basal buds grew. It would appear that in this case the close proximity to water and the consequent better supply may have had the effect of causing growth despite any Loeb effect that would presumably be acting.

The evidence therefore, from (a), (b), (c) and (d) goes to show that there is a bud factor operating in addition to the Loeb effect, and that it explains to a large extent the future behaviour of these buds.

The foregoing facts now make it possible to attempt an explanation of the various stages of growth actually observed.

In the first stage the buds are stimulated to activity by a rise of temperature and the amount of growth is largely a question of their inherent strength, which may possibly be governed by their vascular supply.

As the second stage approaches and conditions of growth are more favourable the Loeb effect begins to tell and the hinder laterals begin to be checked in growth. Gradually they are pulled up unless for some reason the bud is particularly strong. The end of the second stage, marked by stoppage of lateral growth, occurs about the end of April for pears, and about May 20th, three weeks later, for apples.

During the third and last stage in a normal season growth occurs only from a few apical buds. This continues for many weeks and only ceases in a dry summer owing to the lack of water at the roots. The usual dates for pears and apples for stoppage of apical growth is about July 25th and August 15th respectively, and in a wet season such as frequently occurs at Long Ashton, about August 14th and September 30th respectively. Growth in the third stage is, however, subject to some variation in the more abnormal seasons. Thus if the early summer is dry and the late summer wet,

pears often cease terminal growth about the middle of July, but begin again after heavy rain and continue growing until comparatively late. Apples, unless freshly planted, grow continuously without check. Such an alternating season frequently has an effect on laterals that have already been pulled up. Some will grow out under these conditions, making incidentally a very bad type of growth for future flower formation. This growing out may be accounted for by the lessening of the Loeb effect, due to stoppage of terminal growth, and the increase of bud factor by increase of crude sap. It would be expected, therefore, that the most growth would be made by the strongest buds : and this is actually the case.

The above remarks apply very largely to what may be called the average case. For the sake of simplicity the pear, *Vicar of Winkfield*, has been chosen to illustrate many of the points, as in many respects its growth is of a simple character. Behaviour of buds, however, differs in different varieties, and though the general principles already set out seem to apply to all, details may vary considerably. Apples as a class for instance nearly always form more bare wood at the base than do pears. The Loeb effect seems stronger and consequently it is much less easy to divide the twig into well marked sections at the end of the growing season. The region of apical growth graduates more into the region of pulled up laterals, and these too show considerably greater strength toward the apex, as compared with the pear in which they are nearly all equal. Thirdly, as already noted the basal buds in the apple are exceptionally weak. The same kind of variation, though to a less extent, can be found in pears as a class and apples as a class. There are pears that break well like *Vicar of Winkfield* and *Bellissime d'Hiver*, or badly like *Durondeau*. Similarly, there are apples that break well like *Lane's Prince Albert*, moderately like *Cox*, and badly like *Lord Hindlip* or *Worcester Pearmain*. It is not possible yet to put varieties definitely into classes and it must be remembered that there are other factors at work besides variety factors. It has been frequently noticed for instance that varieties which break badly in the wet climate of *Long Ashton* break well in the drier climate of *Hereford*. Nevertheless above all external conditions there is a variety factor at work, and this factor may be observed clearly when different varieties under the same conditions are compared.

Summing up therefore one may say that the growth of buds from a last year's shoot are influenced by the following factors :—

- (a) Temperature.
- (b) Inhibition effect of Loeb.
- (c) Bud strength.
- (d) Root action.
- (e) Variety influence.

III.—THE EFFECT OF NOTCHING AND RINGING ON APPLE TREES.

The practice of ringing is an old one and has been applied by many experimenters, especially to the vine. It dates back to the time when commercial fruit growing was practically unknown, and it is not surprising, therefore, that it is looked askance at by present-day commercial growers. Its main endeavour was to obtain increased fruitfulness and not to obtain scientific information. To many growers who pride themselves on their practical bent this would appear a strong recommendation, but in this, as so frequently elsewhere, the short cut is likely to prove the longest way round. Neither the acceptance of the results of a narrow line of experimentation, nor the obscurantist attitude of the big grower who regards such practices as amateur dabbling, is likely to elicit the underlying principles without which a particular adaptation for use on the large scale may easily be missed. It was with the idea of endeavouring to find these underlying principles that a series of experiments on notching and ringing has been started at Long Ashton. The series is not yet complete, but the results to hand are sufficiently interesting and suggestive to merit publication.

Before setting forth the experiments and results obtained it is worth while to consider the previous work and conclusions of workers in this and other countries. The practice of notching does not seem to be mentioned often, but Passy describes the process of notching above and below, and adds that the process above a bud encourages its growth into a wood shoot and above a wood shoot encourages strength. A notch below a branch is said to weaken growth, though not to the same extent that one above strengthens it. No mention is made of notching below a bud. Vercier figures the notch above and below branches giving the same effect as Passy notes, but no mention is made of the effect of notching above and below buds. Both explain results by the supposition that the sap is stopped by the barrier thus interposed and either forced into or away from the branch concerned.

As regards ringing, both authors claim that it increases fruitfulness and both that it is dangerous, Vercier adding, as an explanation of increased fruitfulness, that the operation causes a piling up of elaborated products in the part above the ring.

Of the American workers on the subject Bailey says that ringing is useful in two ways. Firstly, the operation may cause unproductive trees to bear, and secondly, it may modify the fruit above the ring in the direction of increased size and acceleration of maturity. He explains these two results by the assertion that the obstruction below the bud tends to cut off the supply of sap upon which rapid growth largely depends, but the deposition of elaborated material from the

leaves builds up tissue. The parts above according to his explanation thus tend to thicken rather than elongate. Kains gives the results of several American workers. Thus Drinkard found that after a spring pruning ringing did not affect essentially the amount of fruit set or harvested, and concluded that any effects of ringing were more than overcome by the effect of spring pruning. Maryland, however, found that increased fruitfulness followed ringing, but considered the operation as one to be applied under special conditions only. Many American experiments on ringing grape vines show that the operation hastens maturity and size, but often injures the quality, making the grapes comparatively insipid and too soft for market. These effects, however, vary with the season. Kains gives the results of some ringing experiments of Howe done on standard apples, the ring being made low down on the trunk in midsummer. In some cases he obtained increased fruitfulness; in other cases no result. As a rule the very vigorous trees reacted better than moderate or weak trees. Kains mentions the fact that in one experiment shoots to the number of two to six appeared below the ring. He states that the theory of the operation is:—

“That the removal of a band of bark through the cortex and phloem of a plant, at the period of most vigorous growth, does not hinder the upward passage from the roots to the leaves of unassimilated sap through the outer layers of woody cells, but does prevent the distribution, through the vessels in the cortex and inner bark below the wound, of assimilated food. The effect of this action is to cause an extra amount of reserve material to be stored in the upper parts of the plant for the production of fruit buds.” The fact that sprouts appear below the wound—and he is the only worker to note these—is explained as the endeavour of nature to provide assimilated food for the roots, owing to the passage of such food for the roots from the upper portion of the tree being cut off.

From these excerpts, which do not claim completeness, it will be seen that many workers have tried the effect and noted the results of ringing, and that notching has been long an established practice with the French. The explanations given are not always the same, and, as will be shown later, are not entirely satisfactory to the botanist. The width of the rings were always over an inch and often measured many inches. No attempt has been made as far as the authors are aware to make a complete experiment which should show the effect of rings

- (a) Of various widths.
- (b) In various positions—trunk, main and subsidiary branches etc.,
- (c) At various times of year.

In order to obtain information on these points the following scheme of experiments was arranged at Long Ashton, beginning in 1919.

- (1) Rings were to be made of the following widths, $\frac{1}{4}$ ", $\frac{1}{8}$ ", $\frac{1}{16}$ inches, and knife edge width.
 - (2) On main stem, main branches, subsidiary branches and last year's twigs.
 - (3) In Spring (May 5), Summer (July 22), Autumn and Winter.
- The effect both below and above the ring were to be noted. So far the actual experiment has consisted of the following operations.

Ringing.

- (1) On main trunks of Bramley Seedling bushes of about eight years of age, rings made of $\frac{1}{4}$ ", $\frac{1}{8}$ ", knife edge and interdigitating knife edge cuts. With the first two ringing was done in duplicate, one tree having wax applied to the wound and one tree being left without. In the case of the knife edge ring no bark was actually removed and in the case of interdigitating knife edge cuts, the cuts did not go completely round the trunk but only extended about one third the distance. There were, however, several such cuts on one trunk overlapping each other, though separated vertically by about one inch. The object was not to make a complete barrier, but to put a series of obstructions in the way of material passing through the phloem and cortex. In every case the ring only passed as far as the cambium. No wood was removed or cut into. These rings were made on May 6th and repeated on July 22nd.
- (2) On branches of Bramley Seedling & Newton Wonder, bushes of about 18 years of age, rings were made of $\frac{1}{4}$ ", $\frac{1}{8}$ ", $\frac{1}{16}$ " knife edge interdigitating knife edge. These were done on May 6th and July 22nd.
- (3) On last year's shoots of bushes of King Edward VII and King's Acre Bountiful, of about five years of age, knife edge rings only were made on May 6th and July 22nd. In some a ring was made in every internode on the portion of the twig experimented on, on others in every second internode, and in others on every third internode.

So far rings have been only made in late spring and midsummer, the September operations being purposely left out for reasons explained below. There has thus been no time to ascertain the results, if any, of the operation on the portion of the tree above the ring. The description and discussion therefore will be limited to the results of the operation at and below the ring. Curiously enough only one case has been found amongst the description of other

workers' experiments of any reaction occurring below the ring. The results from the May ringings may be summarised as follows.

- (1) In nearly every case where a portion of the bark (cortex and phloem) was removed, one or more shoots appeared below the ring from dormant buds on bare wood.
- (2) The greater the width of the ring the larger the number of shoots appeared from below.
- (3) In every case callus soon started forming over the wound from the cut edges. Nearly all this callus grew downwards from the lower edge of the upper side of the ring.
- (4) For the same width of ring callus grew much quicker when protected by wax.
- (5) For the same width of ring more shoots appeared below the cut when no wax was applied.
- (6) When callus had completely united across the ring further growth in length of the new shoots ceased.
- (7) These new shoots had long internodes, were of small diameter, and often contracted mildew, especially if in the middle of the tree.
- (8) Knife edge or interdigitating knife-edge rings on main trunks and branches, with one exception, failed to cause the growth of shoots from dormant buds on bare wood below.

From these results one may draw the conclusion that ringing in May causes stimulation of dormant buds on bare wood below, and that the stimulation acts as long as callus has failed to bridge the wound. Knife edge rings on trunks and main branches were filled up by callus before sufficient time had elapsed for dormant buds below to start.

The results from similar treatment in July showed that

- (1) The results were of the same order as the May treatment, but very much less marked.
- (2) The wounds often became infected with Canker. For this reason no rings were made in September as in original scheme.

From these results one may conclude that

- (1) The later the rings are made the less will dormant buds below be stimulated. This conclusion is strengthened by some rings made elsewhere in June, when an intermediate result was obtained.
- (2) The operation in July is dangerous owing to the risk of canker.

The knife edge trials made on last year's shoots were done not with the idea of stimulating completely dormant buds on bare wood, but of finding the effect of the operation on the "breaking" of the twig. The rings were made well towards the base of the shoot amongst buds which there was every reason to think would not break naturally.

The results from the May treatment may be summarised as follows :—

- (1) Rings in every internode in the portion treated caused outgrowth of buds into wood spurs or shoots, the strongest coming on the whole from the most basal, but otherwise the strength appearing to depend on the original strength of the bud. Corresponding buds on untreated twigs of the same tree remained dormant.
- (2) A pruned shoot under the above conditions usually showed stronger outgrowth than an unpruned.
- (3) Rings in alternate internodes over the area treated also caused a good break, but in most cases the shoot immediately below the ring was the strongest of the two. Exception appeared to be due to differences in original strengths of the buds. On the whole the spurs formed by alternate ringing were not so strong as those formed by rings in each internode.
- (4) Rings made in every third internode also caused a good break, but the third bud below the ring was usually weak.

From the results one may draw the conclusion that ringing in May causes growth in buds that would otherwise remain quiescent, that the effect is most marked immediately below the ring, but that at the same time there is a tendency for the stimulus to be accentuated at the base of the twig. Also the growth made by a bud is partly dependent on its original strength. The effect of a knife edge ring on one year old wood is thus to cause one or more buds situated immediately below to start into more active growth than they would if no ring had been made. The ring in every third internode showed that there was a considerable weakening of the effect in the bud situated three below a ring. The question therefore, arises as to how far the influence of a ring extends. As already noted one factor influencing this question is the length of time the ring (even though only a knife edge one), remains unbridged by callus. This is, of course, not only a question of width of ring but also one of activity of growth. These experiments indicated that callus grew more slowly in July than in May, but no exact measurements were taken. Despite this, however, less effect was produced on bare wood below in July than in May after ringing.

There is, however, another factor which greatly influences the result and that is variety. Varieties that usually break badly like Lord Hindlip show but little effect after ringing. A knife edge ring on one year old wood produces practically no effect whatsoever, and even a series of such rings fails to cause much breaking unless the terminal bud has been removed by pruning. The variety factor is certainly a real one, but at present sufficient information is not to hand on which to base any generalisations.

Notching.

This operation has long been known amongst French growers and is employed by them usually to strengthen or weaken any particular shoot.

In these experiments the aim has been to find out the effect on buds rather than shoots. The process consists of removing a crescentic slip of bark and phloem immediately above or below a bud. The operation is best performed with a small sharp knife, only two cuts being necessary, after which the small crescent of tissue can easily be caused to leave the twig. The operation is therefore practically a local ringing.

The following experiments were done on one year old twigs of King's Acre Bountiful and King Edward VII, bushes of about five years of age.

- (1) Notches were made above buds situated towards the basal end. These were in a situation where in untreated twigs but little growth would be made.
- (2) Notches were made below buds on the same bushes on one year old twigs, the buds selected being those which normally would make growth.
- (3) Notches were made alternately above and below from base to apex on one year old twigs.

The result of notching above a bud was in nearly every case that the bud affected made more growth than similar buds situated on untreated twigs. Notching below a bud in every case prevented growth and kept the bud dormant. The two effects were shown very strikingly where both operations were done on the same twig, as in 3. In this case, with the exception of the terminal three buds, which grew into wood shoots, every bud with a notch underneath remained dormant, and every bud with a notch above grew into a very short wood spur.

The conclusion may therefore be drawn that notching underneath weakens, and notching above strengthens and that the effect of the notching only extends to the bud adjacent to it.

TRIAL CIDER ORCHARDS.

By C. T. GIMINGHAM AND O. GROVE.

During the autumn of 1919 visits were paid to all the experimental cider-fruit orchards in the counties of Devon, Gloucester, Monmouth and Somerset, which were planted between 1908 and 1910 with trees supplied by the Station, and a detailed inspection was carried out. These older orchards only were visited, as it was desired where possible to see something of trees actually beginning to bear fruit in appreciable quantities. It is intended to continue these visits to the orchards in Worcester and Hereford next autumn.

In addition to an examination of the trees, samples of soil and subsoil were taken in each orchard and detailed analyses of these samples are in progress. Full data will thus be obtained for purposes of comparison of the general condition, habit of growth, cropping, etc., of trees of certain varieties of cider-fruit of the same age when grown under very varying conditions as regards aspect, climate, soil, etc.

The possible effect of the soil type on the composition of the cider made from any given variety can also be investigated later when larger crops are available. It is unfortunate, from the point of view of obtaining information on subjects of this kind, that no general policy as regards the manuring of the orchards and the treatment of the grass has been followed.

In the following paragraphs will be found brief comparisons of the condition of the trees of the more generally grown varieties, together with notes on points of interest in connection with the analyses of the soils. The analytical figures are given in full in the table on p. 108.

It should, however, be understood that the data at present available are not nearly sufficient to enable definite conclusions to be drawn as to the influence of soil type on the growth of the trees or the composition of the fruit. The present report is to be looked upon as preliminary, the work to be continued from year to year. No attempt has been made to give a detailed history of each orchard as this would have taken up a great deal of space and the details can be found, if required, by reference to previous reports.

By way of general criticism, it may be said that in Gloucester and Monmouth the orchards are almost without exception in

admirable condition, the trees obviously well cared for. The Somerset orchards come next, taken as a whole; whilst those in Devon, with one exception, are not in the condition which might be expected in a county where cider fruit is of so much importance. It must be borne in mind that these remarks and all the following notes refer only to orchards which have been planted not less than nine years. The younger orchards, as already stated, were not visited.

GLOUCESTERSHIRE.

May's Hill, Frampton Cotterell, near Bristol.—Orchard planted 1909 with the following varieties: Cherry Pearmain, Kingston Black, Sweet Alford, Knotted Kernel, Strawberry Norman, Red Foxwhelp, Eggleton Styre, Stubbard, Cherry Norman, and Medaille d'Or. For the first seven years after planting a circle of ground with a 6ft. radius round each tree was kept cultivated. A general feature of the orchard, which slopes towards the N.E., and is rather wet at the lower end, is the better growth of the trees on the higher lying ground, although the lower end is drained. Eggleton Styre, Strawberry Norman, Stubbard, Sweet Alford and Cherry Norman have all formed good trees, which are growing satisfactorily. Kingston Black, Red Foxwhelp and Knotted Kernel have not done quite so well, although fair sized heads have been developed. Cherry Pearmain has done badly, especially in the lower parts of the orchard, most of the trees being small and undeveloped. The Medaille d'Or had been badly damaged by wind and were in 1917 shifted out of the orchard and replanted in an old, better-protected orchard. They had not yet quite recovered from the move.

Three varieties of pears, Taynton Squash, Oldfield and Barland have developed very satisfactorily, Oldfield being the best of the three.

The geological formation (Coal Measures) on which this orchard is situated gives rise, in different localities, to several quite different types of soil. Here the soil is of nice loamy texture, the mechanical analysis showing the various grades of particles to be present in very suitable proportions. There is a distinct change in appearance from surface to subsoil at a depth of about 8 inches, but, mechanically, soil and subsoil are extremely alike. The figures for "total" and "available" phosphoric acid suggest that the soil would respond to manuring with phosphates; and basic slag has already been found to have a marked effect. Samples of soil were taken separately from the higher and lower-ends of the orchard, but no significant differences between the two were found.

Road Farm, Hardwicke Court.—Of the nine varieties in this orchard, planted in 1908, Royal Wilding and Strawberry Norman have done best. The Royal Wilding have made fine trees, but they have not yet started bearing. The Strawberry Normans

had a fair crop. Ecarlative, Eggleton Styre, Sweet Alford and Cummy Norman have done very well, and, with the exception of Eggleton Styre, are bearing well this season. Kingston Black and Skyrme's Kernel had not developed such good trees as the other varieties. The Medaille d'Or's had been re-grafted last year with White Close Pippin, as the trees had been breaking down badly. This difficulty occurs in nearly every orchard in which Medaille d'Or has been planted: the long thin spreading branches laden with fruit breaking and splitting very easily. It is evidently only possible to grow this variety in very sheltered orchards.

Two perry pears, Barland and Oldfield, had formed very good trees; the Oldfield especially had made strong growth, but none had come into proper bearing yet.

Experiments in this orchard proved the advantage of cultivating a 6-feet area round the stem for the first six years. At one end of the orchard a group of large elm trees has had a bad effect on the development of the apples nearest to them.

The orchard received a dressing of farmyard manure in 1917.

The soil is derived from the Lower Lias and is a heavy clay, the subsoil being still more sticky. It will be seen from the analysis that there is a good proportion of coarse and fine sand present, which no doubt prevents this soil from being quite such an intractable clay as many soils on the Lower Lias. Both "total" and "available" potash show high figures, whilst the phosphoric acid is rather low. Both grass and trees would probably benefit by a good dressing of basic slag.

Holms Farm, Lydney Park.—This orchard slopes towards the N.W., and the trees on the higher ground are, upon the whole, better than those near the bottom of the slope. Crémière, Doux Amer and Sweet Coppin have formed very good trees which were bearing a fine crop; they also had a good crop in 1918. Dymock Red had also made very good growth, but the cropping was poor so far. In the second category come Cowarne Red, Chisel Jersey, Knotted Kernel and Yarlinton Mill. Fox-whelp has done badly in this orchard; the trees were small and poorly developed.

A 4-feet area round each tree had been cultivated for the first three years.

The orchard is on soil derived from the Old Red Sandstone. It is the lightest soil of those under consideration in Glos. and Somerset, containing nearly 60% of the sand fractions. It is acid in reaction, the lime requirement figure being in the neighbourhood of 3 tons of chalk (or about $1\frac{1}{2}$ tons quick lime) per acre. The general condition of the trees indicates that an acid reaction of the soil by no means precludes quite good growth, though this is not to say that growth might not be still better if the acidity were corrected. The soil would probably respond to general manuring.

Floodgate Farm, Berkeley Castle.—The orchard is situated on a low lying piece of ground, surrounded on all sides by trees, and with a stream along one side. The trees were in excellent condition. The following varieties were planted: Cap of Liberty, Kingston Black, Improved Pound, Eggleton Styre, Killerton Sweet, Sweet Alford, Cherry Norman, Rouge Bruyere, Royal Jersey and Barland and Moorcroft Pear.

All these varieties have done remarkably well, the special feature of the orchard being Kingston Black, which have grown into fine trees, and were bearing a splendid crop. Cap of Liberty and Royal Jersey were also exceptionally good. On the whole this is the best of the orchards visited. A 6-feet area had been cultivated round the stems up till last year.

This orchard has been manured on various occasions with dung and with liquid manure, and this has undoubtedly had an important effect on the growth of the trees. The area immediately around each tree has also been fairly heavily dressed with road sweepings. It is somewhat remarkable to find such fine trees on such low-lying and apparently wet land. No drainage has been carried out at all events for a great number of years. There is a vigorous growth of grass.

This is a rich alluvial soil. The "available" figures for both potash and phosphoric acid are fairly high and the mechanical analysis indicates a soil of very nice loamy texture. As mentioned above, Kingston Black has done exceptionally well in this orchard and it may be said here that, so far as these analyses go, it would appear that Kingston Black is a variety which gives poor results except on fairly rich soils of good texture—compare, for example, Frampton Cotterell and Berkeley, where Kingston Blacks have done well, with Tibberton and Clutton where they have done poorly.

Tibberton.—Ten varieties were planted in 1909. Of these the Sweet Alford's have done best, forming very good trees and bearing a fair crop. Next in merit come Eggleton Styre, Cap of Liberty and Strawberry Norman, which have all grown well. Cowarne Red has done fairly well, but some of the trees were cankered. Knotted Kernel and Kingston Black had not done very well, especially the latter, which were behind most of the other varieties in development. Dabinett and Medaille d'Or have done so poorly that, with the exception of one Dabinett tree, all have been re-grafted. A 6-feet space has been cultivated round the stems for the first six years.

The orchard lies rather wet at one side. It has not been manured.

The soil, which is heavy and of close-grained texture is derived from the New Red Sandstone (Keeper Marl). As with so many soils on this formation, the "total" potash is very high whilst the available figures is low.

SOMERSETSHIRE.

Barton St. David.—This orchard was planted in 1908 and is one of the best of the 1908 orchards in Somerset. Of the varieties planted, Broadleaf Norman, Cummy Norman, Sweet Coppin and Strawberry Norman have all formed fine trees, which are already cropping well. Sweet Coppin had a very fine crop. Hereford Redstreak has not done very well and the two remaining varieties, Cowarne Red and Skyrme's Kernel are suffering from canker to a certain extent.

Four varieties of pears, Barland, Moorcroft, Oldfield and Taynton Squash had all formed good trees, but had not yet carried any crops.

The orchard has received dressings of dung and liquid manure on various occasions. It is on a very heavy clay soil from the Lower Lias, the true clay fraction being over 30%. Compared with the Hardwicke (Glos.) soil, which is on the same formation, this is much more clayey and contains much less coarse sand. There is, however, a sufficiency of lime to keep it sweet and it is a type of soil on which many of the best mid-Somerset orchards are situated. The "total" potash is very high. It would probably respond to slag.

Clutton, near Bristol.—Eight varieties were planted in 1908. Three of them, Crémière, Neverblight and Sweet Alford, have made very satisfactory growth, especially the two first, Crémière carrying a heavy crop. Eggleton Styres were only fair; Foxwhelps were not very good, with the exception of a few trees; Knotted Kernel had formed quite good trees, but Kingston Blacks had done poorly and were badly cankered. Médaille d'Or's were breaking down badly as usual with this variety. Of the three pears, Barland was the best. Moorcroft and Oldfield had not done quite so well.

No manure has been used.

This is another orchard situated on the Coal Measures, but here the soil is of an entirely different type from that of the Frampton Cotterell (Glos.) orchard. It is a cold, heavy clay soil of bad texture; the mechanical analysis showing a very high proportion of the finer grades of particles, especially fine silt. Also it is very short of lime, having a lime requirement figure of about $2\frac{1}{2}$ tons of chalk (or $1\frac{1}{4}$ tons quick lime) per acre. As compared with the clay soil at Barton St. David, this soil contains considerably less true clay (18.85% as against 32.42%), but the high proportion which the fine silt (22.8%) bears to the clay, and the absence of lime tend to make it behave like a much heavier soil. The analysis suggests that it is not likely to be a suitable soil for fruit. Liming and treatment with basic slag would probably effect considerable improvement.

East Compton, Shepton Mallet.—The soil in this orchard, planted 1908, is very thin and the trees, although doing well at the first,

have since started to canker seriously. The trees are upon the whole of a fairly good size. Sweet Alford and Cherry Norman are the two varieties that have done best in this orchard. Strawberry Norman had formed good size trees, but they are badly cankered. Eggleton Styre has done fairly well. The trees of Foxwhelp, Hereford Redstreak and Skyrme's Kernel are fairly well developed, but again canker is very prevalent. Of the four pears planted, Barland, Moorcroft and Taynton Squash have formed good trees; Oldfield not nearly so good. The pears are cankered to some extent, but not nearly so badly as the apples.

The ground immediately round the trees was cultivated until 1917. No manure has been used.

The orchard is situated near the junction between the Lower Lias and Rhaetic Beds. The soil is heavy and of indifferent texture mechanically and very shallow; it was not possible to take a subsoil sample. The "total" figures for both potash and phosphoric acid are high. The condition of the trees is probably mainly determined by the small depth of soil above the rock in most parts of the orchard.

Woolston, North Cadbury.—The trees in this orchard were mostly planted (1908) amongst older trees and suffered from the growth of lichens on the stems and branches. Yarlington Mill, Tardive Forestier and Eggleton Styre have all made good growth, especially Tardive Forestier, which was bearing a good crop. Foxwhelp and Skyrme's Kernel had not done nearly so well as the first three varieties.

The soil is a heavy loam, analysis indicating a good texture and considerable natural fertility.

Christon Court, Axbridge.—This orchard was planted in 1909 and the trees have upon the whole done well, making good growth during the last three years. This year for the first time good crops have been the rule with most of the varieties. Here, as in most of the other trial orchards placed upon a sloping piece of ground, the trees in the higher lying parts have done best. With the exception of Cherry Norman, which was badly cankered, and Cummy Norman, which had formed rather poor trees, all the varieties had made fairly good growth. Broadleaf Norman, Dymock Red, Harry Masters and Major were the best.

Of the pears, Blakeney Red, Oldfield and Taynton Squash had made good trees. Barland and Butt were not quite so good.

On the geological map the boundary between Carboniferous Limestone and Keuper Marl is marked close to the site of this orchard. The analysis indicates almost certainly that the soil is derived from the latter formation; mechanically and chemically it is very similar to the soils at the Station at Long Ashton. It would probably respond to general manuring.

DEVONSHIRE.

Killerton Home Farm, near Exeter.—This orchard is by far the best of the 1908 trial orchards in Devon, but is not quite comparable with the others, as the land has been kept cultivated. The following varieties have been planted: Cap of Liberty, Black, Foxwhelp, Doux Amer, Improved Pound, Medaille d'Or and Yarlington Mill. All have done very well and had good crops, as was the case two years ago. The trees in this orchard have upon the whole started bearing earlier than in other orchards of the same age. The two best are Yarlington Mill and Improved Pound, both having made very good trees. Medaille d'Or is doing better in this case than in any of the other orchards visited; although the branches are spreading too much, they have not broken down nearly so badly as in other places. This is probably mostly due to the fact that the orchard is well protected from winds.

The soil is a fairly light loam of nice texture and sufficiently well supplied with lime. The only figures in the analysis calling for special comment are those for "available" phosphoric acid in both surface and subsoil. These figures are remarkably high and, as information was supplied that no manure has been applied to the orchard, they are rather difficult to understand.

Lenton Farm, King's Nymphton.—The orchard was planted in 1908 with the following varieties: Cherry Pearmain, Skyrme's Kernel, Broadleaf Norman, Sweet Coppin, Chisel Jersey and Knotted Kernel. The trees are, upon the whole, not very well developed and to a certain extent covered with moss. The situation of the orchard is probably the cause of this trouble, as it lies rather low, surrounded by fairly steep sloping ground. Sweet Coppin, Chisel Jersey and Knotted Kernel were the best, the two first having formed fairly good trees. Next in merit comes Skyrme's Kernel, which had a good crop. The Cherry Pearmain had done badly; the trees were small and nearly ruined by canker. Broadleaf Norman were also affected by this disease, some of the trees being badly attacked.

No manure has been used.

The soil is a medium loam of no very great natural fertility. It suffers from a serious shortage of lime in both surface and subsoil, and has a marked acid reaction. The lime requirement figure for the surface is $4\frac{1}{2}$ tons of chalk (or about $2\frac{1}{4}$ tons quick lime) per acre.

Okehampton.—Planted in 1908 with Cowarne Red, Redstreak, Broadleaf Norman, Cummy Norman, Cherry Norman and Knotted Kernel. The only variety that seems to have done well in this orchard is Knotted Kernel. Of the Norman varieties, the Cherry Norman trees were so badly cankered that they were replaced with other varieties several years ago, and the two others are also suffering badly from the same disease.

No manure has been used.

The soil is very shallow and it was not possible to take a subsoil sample. There again the soil is marked by acid in reaction, the lime requirement figure being about $5\frac{1}{2}$ tons of chalk per acre.

MONMOUTHSHIRE.

The analyses of the soil samples from the Monmouth orchards are not yet complete.

Llansaintfraed.—The orchard was planted in 1908 and is in a very satisfactory condition, the trees being very well looked after. The following varieties were planted: Kingston Black, Redstreak, Eggleton Styre, Medaille d'Or and Knotted Kernel (planted 1909). Kingston Black is the most successful variety in this orchard. Redstreak and Eggleton Styre have formed very good trees, especially the first-named. Medaille d'Or was rather small and liable to break down. Knotted Kernel was doing well, but had not carried any crop yet. All the other varieties had good crops.

The cultivation of an open area round the stems for some years, which has been the practice in most cases in the other counties, has not been carried out here, nor in most of the other Monmouthshire orchards. At time of planting some farmyard manure is applied.

Tre Owen, Dingestow.—Four varieties were planted in 1908: Foxwhelp, Kingston Black, Cherry Norman and Knotted Kernel. Kingston Black and Cherry Norman were the best, both having formed very good trees, which were cropping well. Foxwhelp was somewhat behind in growth. Knotted Kernel has not done well in this orchard. This is exceptional, since otherwise this variety has been very successful in Monmouth.

Itton Court.—Cap of Liberty, Eggleton Styre, Knotted Kernel and Strawberry Norman were planted in 1908, and Kingston Black and Eggleton Styre in 1909. The special feature in this orchard is Cap of Liberty, which has done remarkably well. The Kingston Black is planted in a part of the orchard where the soil is very rocky and with a depth of only 6—8 inches; with exception of a few trees, the variety has not done very well, canker being prevalent. The same is the case with some of the Strawberry Norman trees, though otherwise the variety is doing very well. Eggleton Styre has formed good trees. Knotted Kernel was not quite so good. There have not been any crops in this orchard.

A pear orchard, planted in 1908, with Moorcroft, Barland, Taynton Squash and Oldfield, has not been a success. The Moorcroft and Barland were small trees suffering badly from canker. Taynton Squash and Oldfield were better, but not satisfactory. The orchard

has a thin layer of soil over gravel, and is full of moles. It is surrounded by woods. Probably when the examination of the soil is finished an explanation will be found for the failure of this perry orchard.

Tyllwydd, Llangwn, Usk.—The following varieties were planted in 1908: Cap of Liberty, Kingston Black, Royal Jersey and White Jersey. The orchard is on fairly steep ground, sloping towards the S.W., and the trees on the higher ground have upon the whole done best. Kingston Black has formed very good trees, and the same is the case with Cap of Liberty and White Jersey. Royal Jersey is also very satisfactory, but not quite so good as the other three. There was no crop this year, but the trees have been in bearing. Some basic slag and superphosphate has been used with effect.

Sunny Bank, Rhinoderin.—A very fine orchard, planted in 1908, 9. All the varieties are French. Rouge de Treves, Crémière, Doux Amer and Écarlatine have all formed splendid trees, which are cropping well. The last named variety is suffering a little from canker. Bramtot, Tardive Forestier and Frequin Rouge are very good; they are one year younger than the above. Frequin Rouge had a good crop, but the two other varieties had not started bearing yet. The Rouge Bruyère trees had too much bare wood, and were not quite so good as the others. Médaille d'Or is breaking down.

The orchard slopes towards the S.E. It has had some dressings of farmyard manure.

Croesheolydd, Bassaleg.—Four varieties were planted in 1908 and they have all developed very well and carried fine crops when visited. Fair Maid of Devon, Sweet Alford and Dabinett had formed fine trees. The Chisel Jerseys were rather small in the stem.

No manure has been used except at the start. Two of the trees had been completely barked by moles before planting, but the stems were covered with grafting wax, and this treatment saved them completely.

Llanddewi Court.—This pear orchard was planted in 1908 and has been very successful indeed. Moorcroft has done remarkably well. Barland, Hellen's Green, Oldfield, Pine and Taynton Squash were very good trees, and Butt, Claret, Dandoc and Holmer had developed satisfactorily.

COUNTY CIDER ORCHARDS PLANTED 1908-10

	GLOUCESTERSHIRE.						SOMERSETSHIRE.					DEVONSHIRE.		
	Frampton Cotterell.	Hardwicke.	Lydney.	Berkeley.	Tibberton.	Barton St. David.	Clutton.	East Compton.	Woolston.	Christon.	Kilberton.	Kingsnympton.	Okempton.	
<i>Mechanical Analysis.</i>														
<i>Surface soil.</i>														
Fine Gravel ..	11.07	0.80	0.68	0.28	1.29	0.53	0.65	0.61	2.81	1.21	3.23	1.15	4.40	
Coarse Sand ..	11.35	18.66	20.67	14.71	6.29	6.09	7.27	1.91	2.04	7.56	13.68	5.23	7.28	
Fine Sand ..	34.93	13.81	37.86	19.87	17.12	11.22	17.31	12.89	27.10	13.43	40.11	37.34		
Silt ..	17.44	12.15	13.53	26.94	17.89	10.09	13.66	9.16	22.32	17.73	13.56	21.98		
Fine Silt ..	18.08	19.37	13.27	16.62	22.55	13.39	22.78	25.63	16.35	26.66	13.67	18.49		
Clay ..	5.32	16.72	3.77	8.54	17.44	32.42	18.85	17.71	14.40	19.41	9.07	7.90		
<i>Subsoil.</i>														
Fine Gravel ..	0.96	1.52	1.06	1.15	1.71	0.49	1.52		3.39	0.75	3.24	0.99		
Coarse Sand ..	11.80	14.63	22.84	16.85	4.85	5.06	5.16		2.70	6.48	11.18	2.87		
Fine Sand ..	34.49	11.50	36.87	20.97	17.51	9.67	15.28		25.71	14.32	40.53	37.77		
Silt ..	16.89	11.93	13.19	25.20	14.85	8.88	13.36		22.25	17.0	14.62	21.93		
Fine Silt ..	18.92	20.43	14.98	14.96	20.02	18.88	21.29		15.88	26.28	12.50	20.29		
Clay ..	9.70	26.68	5.37	13.43	29.21	35.35	28.41		19.19	26.63	10.23	8.50		

CHEMICAL ANALYSIS.

<i>Surface Soil.</i>											
Moisture	1.84	5.76	2.01	2.35	4.76	5.92	4.93	6.72	4.09	3.64	1.65
Loss on Ignition	7.61	9.58	7.55	9.01	9.88	13.73	13.07	17.56	10.17	7.39	4.34
Carbonate of Lime	0.44	1.40	nil*	0.38	1.03	3.7	nil†	5.72	0.03	0.62	1.00
Phosphoric Acid (Total)	0.106	0.149	0.15	0.161	0.166	0.197	0.19	0.503	0.364	0.196	0.254
Ditto (Available)	0.016	0.0123	0.0177	0.025	0.025	0.0057	0.02	0.0072	0.0336	0.0405	0.119
Potash (Total)...	0.257	0.629	0.41	0.562	0.771	1.096	0.72	1.453	0.566	1.44	0.503
Ditto (Available)	0.0094	0.0337	0.024	0.016	0.01	0.013	0.013	0.0155	0.0103	0.0058	0.0084
<i>Subsoil.</i>											
Moisture	1.35	5.26	1.55	1.72	5.11	5.51	4.74	3.58	3.58	3.02	1.51
Loss on Ignition	4.68	6.45	4.44	4.77	5.05	8.56	8.01	6.25	6.25	4.22	3.09
Carbonate of Lime	0.44	0.34	—	0.38	0.32	5.38	nil	0.05	0.05	0.20	0.49
Phosphoric Acid (Total)	0.067	0.11	0.114	0.111	0.157	0.153	0.11	0.157	0.409	0.123	0.17
Ditto (Available)	0.0054	0.0076	0.0124	0.0112	0.026	0.0024	0.007	0.0147	0.0147	0.0171	0.062
Potash (Total)...	0.241	0.734	0.381	0.588	0.906	1.204	0.80	0.686	0.686	1.804	0.484
Ditto (Available)	0.0065	0.0168	0.0097	0.01	0.0073	0.0123	0.0117	0.0057	0.0057	0.0064	0.0034
* Lime requirement 0.325%. † Lime requirement 0.24%. ‡ Lime requirement, 0.46%. § Lime requirement, 0.56%.											

The terms Fine Gravel, Coarse Sand, etc., indicate separate fractions of the soil, each composed of particles falling within certain arbitrarily chosen limits of size, "Fine Gravel" being the coarsest and "Clay" the finest.

The above analyses were made in most cases by Mr. T. Wallace.

A SURVEY OF WEST OF ENGLAND FARM ORCHARDS.

BY B. T. P. BARKER.

The formation of an Advisory Committee on Farm Orchards has been referred to in the introductory section of the present Report. As at present constituted it is composed of representatives of the Horticultural Division of the Ministry of Agriculture, three representatives from each of the counties of Devon, Gloucester, Hereford, Monmouth and Worcester, two of whom in each case were appointed by the County Council and one by the Farmers' Union, and several members nominated by the National Fruit and Cider Institute to complete the representation of the various interests concerned. The object of the Committee is the improvement of orcharding in the farms of the West of England.

The deplorable condition of the average farm orchard has now so frequently been drawn attention to that it is needless here to labour that point. It was, however, evident to the Committee at the outset of its deliberations that, while there was no question of the general state of neglect and decay which obtained, it would be difficult to grapple effectively with the task confronting it unless information much more precise and detailed than any available could be secured. A general survey of the 100,000 odd acres of farm orchards in the western counties, obviously could not be completed in a reasonable time: and it was therefore decided that a limited survey of all the orchards in small selected typical districts should be made, which would serve to furnish a sufficient volume of fact upon which the Committee could proceed to base its further action.

The general scheme of the survey was as follows. In each county three localities were selected as centres, within a radius of two or three miles around which all farm orchards above about an acre in size were inspected in detail. The choice of locality was left to the discretion of the County Agricultural Education Authority concerned, subject to the stipulation that each district was a fair and representative one for the county as a whole. Schedules of particulars to be noted in each orchard were drawn up. These

were exhaustive in character and referred to such points as the character of the soil, the situation, age and condition of trees, varieties, state as regards disease and prevalence of individual pests, and so on. The survey was made by the Horticultural Instructor for the county in conjunction with two of the inspectors of the Horticultural Division of the Ministry of Agriculture, Messrs. Turner and Whiting, whose services were placed for this purpose at the disposal of the Committee by the Ministry. Where possible, members of the staff of the Institute co-operated also. In order to gain as much information as possible about varieties the orchard inspections were made during the months of September and October.

Owing to various causes the survey was not quite so complete as had been hoped. In the end neither the Hereford nor Monmouth authorities found themselves able to participate, but on the other hand Wiltshire ultimately was included in addition to the remainder of the counties named above.

The following table gives particulars of the area actually surveyed :

<i>County</i>	<i>Acreage</i>	<i>No. of Orchards</i>	<i>No. of Occupiers</i>
Devon	103·746	45	31
Gloucester	342·515	87	32
Somerset	91·838	43	17
Wiltshire	105·500	39	43
Worcester	1,136·850	317	32
TOTALS	2,880·449	531	155

To attempt to give anything more than a bare outline of the results of the survey here is out of the question on account of considerations of space. The completed schedules for each individual orchard were carefully examined in detail previous to the drafting of a general report, and have now been filed for reference when required. Reports for each county and for the area as a whole have been prepared by Messrs. Turner and Whiting and are about to be considered by the Committee, which will then decide as to the next step to be taken. From these reports the following particulars of the survey have been taken, and thanks are due to the gentlemen named for their use for the present purpose.

Broadly speaking, the survey has fully confirmed the pessimistic views current as to the thoroughly unsatisfactory condition of orcharding in the district. Apart from a few outstanding exceptions it furnishes a most depressing story of indifference and neglect, combined in some cases with complete ignorance not only of cultural practice but also of the market value of the fruit already being produced.

Mr. Gaut, the Agricultural Organiser for Worcestershire, has analysed the results for that county and they serve to give a very

fair idea of the situation as it stands at present. He has grouped the orchards of the greater part of the area which he surveyed personally, into four classes, according to their condition, and a rather lenient standard has been adopted.

GROUP A includes first-class and good orchards. These have been and are being looked after, though in many cases improvements could be effected.

GROUP B consists of second-class orchards, which are in fair condition and require chiefly cleaning up, pruning, thinning, and some planting up of gaps.

GROUP C is comprised of third-class orchards, in which most of the trees have got distinctly past their prime. They are gappy and full of dead wood.

GROUP D embraces the remainder, which show at least 60 per cent. of gaps. They are fast disappearing and many might almost be described as non-existent.

The actual acreages were as follows. Group A, $176\frac{3}{4}$ acres; Group B, $319\frac{1}{2}$ acres; Group C, $230\frac{1}{4}$ acres; and Group D, $244\frac{1}{2}$ acres. Expressed in percentages, Group A, 18 per cent.; Group B, 33 per cent.; Group C, 24 per cent.; and Group D, 25 per cent. In other words 25 per cent of the orchards are negligible, and another 24 per cent. fast becoming so. Of the remaining half only about one-third can be considered satisfactory, *i.e.*, one-sixth of the whole.

But bad as the general state of affairs is, it is evident that the degree of badness differs considerably in different districts, irrespective altogether of the effect of local conditions. Some of the counties are distinctly below others in standard, and in each county there is usually an appreciable difference as between one district and another. This goes to show that the state of the orchards reflects in a general way the degree of interest, or, rather, the lack of it, which has been taken in them up to the present; and the few good examples which have been encountered certainly serve to encourage any movement for betterment in that they demonstrate that it is possible to grow good fruit on the farm under average conditions in the West of England, and, what is of more importance, to grow it profitably, given a reasonable amount of interest and attention on the part of those directly concerned. It is not proposed here to deal further with the reports on individual districts, since the main purpose of this article is to consider the lessons of the survey in their bearing on the future of farm orcharding, more particularly in relation to the supply of apples and to the cider industry; but it is due to the county of Gloucester that mention should be made that it stands distinctly in advance of the other counties as regards the general state of the orchards surveyed.

Before proceeding further, the chief defects which have been noted in the orchards may be indicated. They may be summarised as follows :—

- (1) In some orchards the situation and aspect is unfavourable to the successful growing of fruit on grass orchard lines. A few are on poor soils, which have run out and become sour.
- (2) The trees originally planted were set out too close and at irregular distances. Replacements have been made with similar irregularity.
- (3) Many trees are badly shaped through neglect in pruning, and in forming a well-balanced head when young.
- (4) A superabundance of dead and diseased wood exists, caused by crowded planting and neglect of thinning at proper intervals. When thinning has been attempted, it has often been too severe in one season and badly done.
- (5) Trees are frequently covered with moss and lichen, which probably form harbouring places for pests and may render the orchards liable to severe and constant attacks in some seasons. The trees themselves are stunted and lowered in vitality.
- (6) The pastures are usually very badly neglected and need to be better grazed and manured.
- (7) High hedges and hedgerow timber frequently shade, overhang and close in the orchards, excluding air and light essential to the healthy development of the trees and pasture.
- (8) Bad systems of both bottom and surface drainage have been frequently noted and lack of attention to existing drains and water courses is common.
- (9) A large proportion of trees have been badly damaged by avoidable causes, such as rough and careless gathering of fruit, animals of an unsuitable character, *e.g.*, colts, turned in to graze, cattle rubbing, rabbits and hares, defective staking, and a variety of insects and fungoid pests, especially woolly aphis and canker.
- (10) The varieties of apples grown are far too numerous and have been indiscriminately selected at planting time. Many are utterly worthless, possessing neither market nor vintage value ; others are bad growers and croppers ; and a large proportion are far too susceptible to attacks of the common pests.

A variety of causes have contributed towards this deplorable result. The most direct and immediate, perhaps, is that the attention needed to dispose profitably of the fruit, and the secondary consideration to the care of the orchards which at the best of times is the most that can be given by the general farmer, have in course of time lowered the personal estimation of the value set upon an orchard. Instead of it being, as it well might be or have been, the most profitable part of the farm, it is too often in the eyes of the farmer unremunerative and something which he would be glad to be rid of.

The system of tenure under which the orchards are held by the farmer is probably more than any other single cause at the root of the trouble. While the exact terms of the agreement as to the tenure of a holding vary somewhat in different districts, the general practice is in the direction of an annual or short term tenancy. The orcharding is let as a part of the farm without separate treatment. In most cases the tenant is expected to replace trees at his own expense, or if the landlord, as in some instances, provides them, the responsibility for their care devolves on the tenant. When vacating a farm the latter receives no consideration for the condition of the orcharding and no allowance for improvements effected by him. Under such circumstances there is little inducement for him to do more than fulfil his nominal obligations. Standard trees take too long a period to come into profitable bearing for him to take much interest in newly planted trees, with the result that by the time they are old enough to bear crops of account their value has been seriously depreciated by neglect.

Another contributory cause of the first order is the kind of tacit understanding between landlord and tenant which appears to exist more or less generally and according to which, provided that the number of trees in the orchard is maintained, it does not matter what they are, what their condition is, or how they are treated. Lack of interest on the part of the landlord and lack of attention on the part of the tenant have together had the effect of a sustained effort to depreciate the value of the property. A strong reason for the tenant's neglect has been indicated in the previous paragraph. It is more difficult to understand the owner's indifference towards the upkeep of his property in good condition, unless it is that he does not realise the potential value of a well-ordered orchard. Many have evidently been discouraged after spending considerable sums on trees and fencing by the culpable negligence of tenants. Unwilling to exact any penalty, they appear to have allowed the orchards to take care of themselves subsequently.

Again, many farmers of to-day have not the interest and knowledge of orchard work possessed by those of the previous generation. They have inherited a legacy of orchards past their prime and are

content to see them decay. The local labour skilled in orchard work has to a great extent passed away and its place has not been adequately filled by the present generation. Of late farmers have found it difficult to get pruners and grafters whom they could trust to do the work.

Still one further factor of importance tending towards orchard neglect remains to be mentioned, viz., the inadequacy of facilities to enable the farmer to turn the produce of his orchards to most profitable account. The orchards at present consist mainly of trees in overwhelming preponderance of varieties fit only for cider. The consumption of cider on the farms has decreased greatly, and is still doing so rapidly. The average farmer, however, is neither in a position to make cider for sale capable of commanding a good price, nor has he the time to devote to it. If he has made his fruit into cider in the past, he has had to be content with unremunerative prices. If he has sold it to a cider manufacturer, his returns have often been very disappointing. As for any fruit fit for table purposes, most of it is sold as pot fruit, at relatively low rates, and the farmer frequently has no idea of its actual market value. As an illustration a case met with in the Worcester survey may be recorded, where Blenheim Orange and King of the Pippins apples were being sold at £5 per ton, when if they had been sorted, graded and packed moderately well they could have realised £25 to £30 per ton.

Such, then, are the general conditions which the survey has revealed. They need to be considered in conjunction with the facts (a) that the official returns of the Ministry of Agriculture show that the scheduled area of grass orchards in the West of England is diminishing at an alarming rate, the decrease amounting to 27,500 acres in the last ten years, *i.e.*, about one-fifth of the total area; and (b) that during the course of the survey very few orchards less than 25 years old were met with, or, in other words, that the planting of new orchards has practically ceased.

The seriousness of the position from the point of view of the cider industry can hardly be exaggerated. If the present course of events continues unchecked, a shortage in supplies of cider fruit will begin to be felt before many years have elapsed, and the industry will be practically extinguished within 50 years for lack of raw material. A truly alarming prospect for an industry which during the last few years has shown signs of rapid development!

The position is in reality worse than appears on the surface. While the majority of farmers are indifferent to their orchards and are doing nothing to maintain them, the minority who are more interested are making a definite move towards the replacement of cider varieties by table sorts in their orchards, both by planting the latter instead of the former when new trees are required and also by re-grafting some of the existing cider trees with those kinds.

The survey thus brings up for urgent consideration two main questions. Firstly, in view of the state of affairs revealed by it, is it a sound policy to encourage apple growing in this country under the farm orchard system? Secondly, if the answer to the preceding is in the affirmative, is it preferable to grow vintage or table varieties?

Dealing with the former first, the results of the survey surely supply the answer that it must be contrary to the national interest that a large area of valuable land should be permanently rendered relatively unproductive by its use for orcharding on the lines hitherto prevailing. The old system must be regarded as a failure under present-day conditions. At the same time the fact that a well-managed orchard can be made the most profitable part of the farm must not be overlooked: and it would be wrong to condemn the farm orchard solely because under a system of tenure and management which is obviously radically bad, the existing orchards have drifted into the present state of decay. The question, therefore, resolves itself into one of a different character and becomes as follows. Can the prevailing conditions of tenure and management be modified in a way which will enable the farm orchard to be a source of real profit and a sound investment for owner and tenant? To judge from instances met with during the course of the survey it is beyond doubt that they can. The steps necessary to ensure this desirable result can be but briefly indicated here.

In the first place, it is evident that until the farmer is assured that he will reap some benefit from the care he may bestow on the orchard and the improvements he may be able to effect, his attitude must inevitably tend to be one of indifference. An arrangement ensuring him a return for his interest and effort must be arrived at between the landlord and himself. The Evesham custom in this respect seems a sound one; and there are other alternatives which have been adopted in isolated cases which are also worth consideration.

A more direct interest on the part of the landowner is also needed. Few appear to appreciate the capital value of a good orchard. If due care of this part of a property were insisted on and the tenant held liable—actually as well as nominally—for depreciation due to neglect, a good standard should be maintained throughout the life of an orchard.

In the average case, since orcharding under these conditions is merely an adjunct to general farming, neither the owner nor tenant can be expected to have the knowledge of fruit culture possessed by the more specialised professional fruit growers; and many defects in the orchards in the past have been due primarily to lack of knowledge of the subject. Provision ought, therefore, to be made for skilled advice and supervision in some form. In this direction the County Council authorities through their horticultural instructors

ought to be able to render good service. With the responsibilities which are being placed upon County Agricultural Committees in connection with badly farmed land it would seem that in any case the questions of derelict orchards will sooner or later receive their attention and that an effort will be made to renovate or else to utilise the land to better purpose.

The first step towards improvement, therefore, is to secure, if possible, united action by owner, tenant, and local authority in a systematic attempt to bring the farm orchard into a better state of cultivation.

By what means can the orchards be converted into a more profitable condition? In some cases, where soil or situation is obviously bad or where the trees have gone too far to respond to treatment the sooner the land is put to some other use the better. A large proportion, however, should repay attention.

As regards treatment, in most cases the number of trees should be reduced. Although the orchard probably more often than not will not lend itself to systematic reduction, if all worn out trees and some of those of the more worthless varieties are removed, the remainder will have a better chance of producing good fruit and should eventually give a higher return per acre. The minimum distance apart to be aimed at should be from 28 to 30 feet. From the trees allowed to remain all dead wood and damaged lower branches should be taken off. If the tree is then still too densely crowded with branches, judicious thinning should be practised; but care must be taken not to make this too severe in the one season. It is better to spread this operation over a series of years. Some effort should also be made to clean the trees by means of a winter caustic wash or a lime wash in the spring. In the case of trees of varieties of inferior quality re-grafting with a superior kind may be advocated where the tree itself is suitable for head-working. Where re-planting is necessary, the young trees should not occupy the same stations as those whose places they are to fill, if this can be avoided. Care in the selection of varieties for planting should be exercised. A recommendation as to sorts for planting or top-grafting is made below. Newly planted trees should, of course, be properly staked and cared for until thoroughly established, and for the first few years the ground around the base of the tree should be kept clear of grass and weeds. It may not be practicable to devote the same amount of attention to spraying and other measures of pest control in a farm orchard as in a commercial fruit plantation, but it is important to maintain the general health of the trees at as high a standard as possible. For that reason overcrowding must be avoided as well as a stagnant atmosphere resulting from over-developed hedges and hedgerow timber; proper drainage should be secured, and the condition of the grass improved by close feeding, harrowing and dressings of manure,

By following along these lines a marked improvement in many existing orchards could be effected within a few years. Time must be allowed, however, for bad condition to be remedied if of long-standing, and immediate response may not be very marked.

But if it be granted that the farm orchard under improved conditions, such as those just indicated, can become a source of profit to owner and tenant, the soundness of the policy of encouraging the development of apple culture on a farm where general farming is the main concern of the occupier still remains to be established. In this connection there are wider interests to consider.

So far as the cider industry is concerned, the production of cider fruit on the farm is perhaps the only way of ensuring a supply of the raw material of the industry. A few well-established firms might possibly to a greater or less degree be prepared to grow for themselves the fruit required for their business; but the needs of the trade in general are not going to be met in this way, since it is inconceivable that the smaller makers would purchase land for orchard planting, farm it themselves, and wait years for the trees to come into profitable bearing. The farm orchard, therefore, is necessary for the cider industry.

Its place in relation to the culture of market fruit is more debateable. There is an important and rapidly growing industry of commercial fruit culture in this country and its interests must be taken into account. Were the markets to be flooded with low-grade, inferior apples of the better varieties from farm orchards, as occurs to-day to a limited degree, the commercial grower would have reasonable ground for complaint. It is true that graded fruit of better quality would hold its own, but prices would certainly be affected. The cost of fruit production in a farm orchard being small as compared with that grown on a fruit farm, the latter could not compete on equal terms. So long as the market is not spoilt by inferior fruit dumped from farm orchards, competition is legitimate and in that case the commercial grower would have to bow to the inevitable if his rival on account of cheaper production could afford to sell fruit of good quality at a lower rate. It is indisputable that fruit of the highest quality can be grown in the farm orchard, since during the course of the survey instances occurred where fruit was found which surpassed in quality anything of the same varieties exhibited at the commercial fruit shows held last autumn. Where the farm orchard falls behind the commercial plantation is in the lower proportion of first-grade fruit to that of the lower grades.

To sum up, it would appear that, given favourable conditions, both cider and market fruit should be grown in farm orchards. As to what constitutes favourable conditions, it is perfectly clear that the matter centres round the farmer himself. If he is prepared to devote reasonable attention to his orchards and to grade his fruit,

sending the better quality to the markets and the inferior material to the jam and cider trades, he will not be an unfair competitor in the markets and will stand to gain a handsome return. If, on the other hand, he is not prepared to do more than give the orchard the minimum amount of attention necessary to maintain it in a healthy condition and will not grade his fruit, he should be urged to confine himself to the production of fruit for jam and cider-making. If he will not take even that limited amount of care, it is better in every way that he should be without an orchard.

The point has been raised as to the wisdom of advocating the culture of cider fruit when market fruit can be grown so successfully in farm orchards and can command a much higher price. Leaving out of account the needs of the cider industry, the question is purely a financial one. There is, unfortunately, little direct information on the subject available, and the case can thus only be considered in a general way. Admitting that the gross returns in a particular season may be much higher from an orchard of market fruit than from one of vintage fruit, it is at least doubtful if over a series of years the net profit shows any wide difference in the two cases. Vintage varieties generally are very hardy and prolific. They bear very regularly and withstand unfavourable conditions better than market kinds. No questions of grading and quality are involved. The cost of gathering is relatively very low and much less labour is required. The expenses in connection with distribution and marketing are small. The tendency as regards market value is certain to be in an upward direction with the commercial cider industry increasing rapidly and the supplies of fruit diminishing. A wholesale change from the cultivation of cider fruit to that of market fruit in farm orchards would soon result in a very greatly increased supply of the latter in the markets and prices would tend to fall, especially for low-grade and ungraded fruit. In addition, if the grower of cider fruit will in future grow only a limited number of vintage varieties of the best quality, and those in bulk, he will command for it a much higher price relatively than he has been able to do in the past with his miscellaneous collection of sorts.

The sound policy to recommend is probably a judicious combination of market and vintage varieties, where the grower is prepared to devote a fair amount of attention to his orchards and to grade the market fruit; in other cases, to concentrate on vintage fruit.

As regards varieties, it is obvious that only sorts which make good strong, healthy and erect standard trees when grown in grass are worth consideration. Pendulous varieties are debarred because of their unsuitable habit in an orchard which is to be grazed. The survey has shown that for market varieties Bramley's Seedling, Blenheim Orange, Annie Elizabeth and Newton Wonder can be

recommended with confidence for the whole Western district. A few other varieties, *e.g.*, King of the Pippins and Warner's King in some localities north of Gloucester, occasionally are very successful, but are not generally so reliable as the preceding.

It is not so easy to make recommendations for vintage varieties. Few kinds are grown widely enough to enable any satisfactory estimate of their general suitability to be formed. So far as they go, the trial orchards established by the Institute in many localities have provided useful information, but they have only afforded a limited test of a relatively small number of kinds. However, the sorts enumerated in the accompanying list promise well for general culture. A somewhat large number must be put forward, because the sharp, sweet and bittersweet classes must be represented and the season for the fruit must be of long duration in order that there shall not be an impossible rush of work in the cider factories caused by the fruit all coming in at once. For those reasons nine classes of varieties must be provided, *viz.*, early, mid-season, and late kinds of each of the three sections, "sharps," "sweets," and "bittersweets." The varieties, moreover, must obviously possess vintage value as well as adequate orchard characters. In making a selection regard has also been paid to another character, *viz.*, value for general market purposes or for jam-making. It is clear that, other characters being more or less equal, it is preferable to grow sorts for cider-making which can, if needed, command a market for eating or jam purposes. Such sorts may be termed "dual purpose" varieties. The accompanying list consists mainly of such kinds, and they are indicated by their names being printed in italics. The remaining point considered in making the selection has been that of size of fruit. The advantages of a good-sized apple are its greater value for market and its greater convenience and lower cost for gathering.

Regarded exclusively from a cider point of view, the list of selections is not the strongest possible, and a few varieties of low vintage value, *e.g.*, Morgan Sweet, are included because they make most profitable orchard trees. Their vintage deficiencies, however, may be counteracted by judicious blending with the other selected vintage sorts of their season. The aim has been to make a selection which will render the farm orchard as profitable as possible consistent with the production of cider of good quality. It is useless recommending varieties of high vintage quality but inferior orchard character.

When planting new trees growers are advised to concentrate on the varieties named, since it is all-important to restrict the number of kinds grown. The nurserymen of the West of England have intimated that they are prepared to propagate those kinds extensively if there is likely to be an assured demand.

LIST OF VINTAGE VARIETIES FOR FARM ORCHARDS.

CIDER APPLES.	SHARP.	SWEET.	BITTERSWEET.
EARLY .. (to end of Oct.)	<i>Backwell Red</i> <i>Tom Putt</i>	<i>Court Royal</i> <i>Morgan Sweet</i> <i>Sweet Coppin</i> <i>White Jersey</i>	Knotted Kernel Major
MID-SEASON .. (November)	<i>Cap of Liberty</i> (syn. <i>Red Soldier</i>) <i>Crimson King</i> <i>Dymock Red</i> <i>Foxwhelp</i> <i>Kingston Black</i>	<i>Eggleton Styre</i> <i>Improved Pound</i> (syn. <i>Sweet Blenheim</i>) <i>Sweet Alford</i>	<i>White Close Pippin</i> <i>Yarlington Mill</i> <i>Jersey</i>
LATE .. (December and January)	<i>Greasy Pippin</i> <i>Ponsford</i> <i>Reinette Obry</i>	<i>Slack-ma-Girdle</i> <i>Thomas Hunt</i>	<i>Chisel Jersey</i> <i>Royal Wilding</i>
PERRY PEARS		<i>Butt</i> <i>Oldfield</i>	

In conclusion the hope may be expressed that the survey will not be permitted to be barren of result. It has revealed a deplorable state of affairs, relieved only by occasional glimpses of the possibilities of farm orchards. At a time when, more than ever, it is necessary that the resources of the country should be developed to their utmost, it is against the national interest that so large an area of valuable land should fail to produce its fair share. While the Institute has done its part in exposing the situation and in endeavouring to indicate a constructive policy of improvement, it can do relatively little further except in co-operation with all the other interests concerned.

The task of removing the stigma now attaching to the West of England farm orchards and of reinstating them in the position of centres for the production of fruit of the highest quality, for which they are well fitted by reason of the favourable natural conditions, is one which can only be accomplished by united effort on the part of all concerned.

ADVISORY WORK.

The number of enquiries received during the year was 202 as compared with 173 the previous year, and with 133 for the year ended September 30th, 1917. As in the previous year the enquiries have been mostly concerned with Horticulture rather than Agriculture.

The following table shows the source of the enquiries :—

Gloucester (including Bristol	...	...	29
Hereford	...	...	6
Somerset	...	...	75
Wiltshire	...	...	6
Worcester	...	...	11
Counties outside the Bristol Province	...	...	75

202

The latter figure includes enquiries from Devon and Monmouth, which counties contribute an annual grant to the Institute.

Nature of Enquiries.—The majority of the enquiries have been concerned with various aspects of fruit culture, including plant diseases and their treatment, and of cider making. There has been very little of special interest in the enquiries which have been sent in. Generally they have been of the same character and are concerned with the same problems as those received in previous years, which have been already mentioned specifically in the Reports for those years. The following are among the more interesting questions which have been brought to notice :—

Narcissus bulbs attacked by *Rhizoctonia* sp.

Scots Pine seedlings attacked by *Pythium de Baryanum* and *Fusarium pini*.

A form of dry rot of timber.

Potatoes attacked by *Verticillium albo-atrum*.

Red Currant bushes attacked by *Cystosporina* sp.

Malformation of tomato fruits and stems due to physiological causes.

Bud rot of apples, caused by a *Fusarium* sp.

Malformation of pears, probably analogous to bitter pit in apples.

A form of Potato Scab, probably caused by *Actinomyces*.

Bud rot of pears, caused by *Fusarium* sp., the same form responsible for apple bud rot. (First case observed.)

Peach mildew, caused by *Sphaerotheca pannosa*. This fungus does not commonly infect the peach in this country, but is prevalent on this host in the United States.

Currants attacked by *Cronartium ribicola*.

Tomatoes attacked by *Phytophthora cryptogea*.

Disease of plum trees due apparently to bacterial attack of the bark of the main stem. Many cases have been observed and large numbers of trees are being killed off by this disease, which has only recently come under serious notice.

An unusual type of chlorosis, the cause of which has not yet been ascertained.

A severe case of splitting of fruits of Cox's Orange Pippin apple, during ripening, due probably to check of growth during early development brought about by drought.

Defective pollination of walnuts.

The use of yeast for cattle food.

Stimulants for yeast growth in slow-fermenting apple juices.

SPECIAL INVESTIGATIONS UNDERTAKEN AS THE RESULT OF ENQUIRIES.

(1) *The treatment of Rhizoctonia disease of Asparagus*.—The field trials which have been conducted at Badsey, near Evesham, for a number of years past, have been continued during the year with some modifications. The action of bleaching powder and creosote has been more particularly tested in view of the promising results obtained earlier. The results for the season were unfortunately negative, since while the disease did not appear on the treated plots, it also failed to show itself on the control untreated plots. It would seem that the exceptionally dry weather in the early part of summer was unfavorable to the appearance of the disease.

(2) *Apple Leaf Scorch*.—Investigations on this subject are being continued. Further results of interest have been obtained, but definite conclusions cannot be drawn at present.

(3) *The Manurial Value of Horsehair Refuse*.—The field trials of this material have been continued during the year, and show that it is of appreciable value as a source of nitrogen. Further trials are desirable.

The following sections dealing with the Advisory work in Agricultural Chemistry and Economic Entomology have been contributed respectively by Mr. C. T. Gimingham and Mr. A. H. Lees, the advisers in those subjects.

AGRICULTURAL CHEMISTRY.

Ten requests for advice as to the manuring or other treatment of grass, arable or fruit land have been dealt with (seven from Somerset, and one each from Devon, Worcestershire, and Wiltshire). In most cases these have involved a visit to the farm concerned, and the collection of samples of soil. In all the analyses of thirteen samples of soil have been carried out in connection with these problems.

Among miscellaneous enquiries replied to, the following may be mentioned :—

- (1) Advice as to the suitability of arsenate of lead powder for insecticide purposes.
- (2) Advice as to the use of low grade shoddy.
- (3) Advice as to the value of " native guano."
- (4) Advice as to the use of Potash manures.
- (5) Advice as to the value of spent hops as manure.
- (6) Determination of potash in haystack ash.
- (7) Analysis of a low grade organic manure.
- (8) Joint investigation of a case of apparent chlorosis.
- (9) Advice as to the use of cider apples for feeding purposes.
- (10) Joint experiments on the treatment of grass land infested with the larvae of *Phyllopertha horticola*.

ECONOMIC ENTOMOLOGY.

The subjects dealt with were as follows :—

Insects	...	...	...	18	enquiries.
Fruit questions	...	...	...	12	"
Sprays	...	...	...	9	"
Diseases	...	...	...	6	"
Miscellaneous	...	...	...	5	"

Under the heading of " Insects " all other economic groups such as Myreapoda, Arachnida and Mollusca are included.

The " fruit question " dealt with such subjects as pruning, training varieties, suitable conditions, manuring, and literature.

" Diseases " indicates maladies other than those caused by fungi or insect pests.

In addition, eleven visits were made by requests of growers in reference to the above enquiries.

The year thus shows a decided increase in the number of enquiries sent through the post, and a very decided tendency for growers to make more use of this advisory department.

As might be expected, it is the growers who have recently taken up fruit growing who make the most applications, but there has been also a marked tendency this year for old established growers to request advisory visits. In this connection the practice of paying visits to such growers has been continued, a fortnight being thus spent in May and another fortnight in September. The advice given has by no means been confined to insect pest questions ; the recent results of research in fruit bud formation with the allied subject of pruning have been largely dealt with.

On the whole it may be said that there is a well marked and increasing inclination on the part of growers to make use of the facilities afforded them.